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Vol. 202 AUGUST, 1926 No. 2

A CELESTIAL ENCOUNTER.*

BY

ERNEST WILLIAM BROWN, Sc.D.
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ON THE morning of Saturday, January 24, 1925, the State of Connecticut suspended its daily life for half an hour in order to see the most striking spectacle of the skies—a total eclipse of the sun. From factories, stores, offices, banks, schools, colleges, hundreds of thousands of men, women and children were collected on roofs, at windows, and in the open. Other states poured their tens of thousands into the shadow track by automobile, trolley, and railroad. A dirigible and many airplanes sought special views aloft. Photographic cameras and radio sets were in operation in uncounted numbers and ubiquitous news reporters lost no phase of the situation. In a few favored spots small handfuls of astronomers were working quietly but at high speed to learn more about the heavens.

The stage was set some four years before when the Nautical Almanac Office at Washington, which is entrusted with the duty of furnishing predictions of the positions of the heavenly bodies, announced that the moon would hide the sun from a small portion of the earth on that morning, and that the shadow track would cross nearly the whole of the state. It foretold the northern and

* This paper is, in substance, a lecture given before the Institute on November 18, 1925. In its present form, it is reprinted with some omissions from *History of Connecticut* with permission of the States History Company, Inc.

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southern limits of this track within a mile and the time at which the shadow would arrive within a second or so, and no responsible astronomer doubted the prediction any more than he doubted the daily rising of the sun. He started in with his preparations for observing the event with full confidence that it would occur according to the prediction. The only doubt was whether the fickle atmosphere would permit him to see what was taking place beyond the earth. His brother, the meteorologist, has not yet succeeded in advancing his science to the point where the behavior of the air can be foretold long in advance. Only the chance for good weather can be given and that chance must be taken.

Eclipses of the sun are not rare events. At least two occur every year and there may be as many as five. But a considerable proportion of these are only partial, that is, at no spot on the earth is the sun completely covered by the moon at any moment during such an eclipse. A total eclipse occurs nearly every year, but the part of the earth from which the sun is completely hidden is only a narrow track not more than a couple of hundred miles wide, though it may be some four thousand miles long. At the most favorable time it will only cover about one hundredth part of the earth's surface, and in most cases the area is much smaller. The result is that any particular spot on the earth will only be visited by a total eclipse on the average once every few centuries. According to the records, Edinburgh has had five total eclipses in the last thirteen hundred years, while London has not had more than two. The danger of setting a precedent, which was voiced by a teacher in one of our institutions when it was proposed to suspend the exercises for the present occasion, is certainly not one which need cause any serious alarm.

THE TRACK OF THE SHADOW.

In the eclipse of January 24, 1925, the band of totality, as the area from which the light of the sun is completely excluded is called, started at sunrise somewhat to the west of Duluth, a city placed very near its southern border. From there the shadow travelled at over a mile a second towards the east and a little to the south, crossing the northern parts of the State of Michigan, the province of Ontario, entering New York State with Buffalo on its central line. Thence, gradually slowing down to some fifty miles a minute, it covered nearly the whole of the State of

Connecticut. It then passed out into the Atlantic Ocean, getting as far south as latitude 40°, where it was travelling about half a mile a second. Moving north again with increasing speed, it ended at sunset in the sea to the north of Scotland.

The whole time of its passage across the earth was less than two hours, the six hours difference of time between the places where it was first seen and where it disappeared accounting for the fact that it appears at sunrise in one place and ends at sunset in another. The daily rotation of the earth from west to east causes the State of Connecticut to travel about twelve miles a minute. The shadow travelled in the same direction but much faster. If the moon took three months, instead of one, to get round the earth, the shadow would stay in the same place on the earth for a considerable part of the day and that spot would be the only place from which an effective view could be obtained.

The State of Connecticut was more highly favored for the observation of the eclipse than any other part of the land. The sun was higher in the sky—about 18° above the horizon—the time of totality longer, being some two minutes, and the chances for fine weather were nearly 50 per cent. In the middle of the Atlantic Ocean the sun was twice as high, but the time was only longer by half a minute. For the ordinary spectator the view there would be as good as on land, perhaps better if he were reasonably free from bodily discomfort.

But for the astronomer the ocean is almost out of the question. The latter now does nearly all his work by photography and he needs a steady platform for his instruments if he is to keep them pointed at the sun during the exposures. It was not strange, therefore, that observatories all over the country sent representatives to this state to obtain records which could be studied at leisure. Most of them placed their instruments either on the grounds of the Yale University Observatory in New Haven or in the buildings of the Van Vleck Observatory of Wesleyan University, in Middletown. For the astronomer it is usually all or nothing. Those who came took the chance of having fine weather and were rewarded by skies which will make this eclipse one of the most famous in all history. Some of them had been to California in September, 1923, where the chances for cloudless views were nearly a hundred per cent.; only to be baffled by a storm which prevented any observation of the sun. One or two parties, how-

ever, had taken their stand in northern Mexico with much poorer chances of fine weather and had the good fortune to secure complete records owing to a break in the clouds which occurred at the critical moment.

ORGANIZATION.

Such were the facts in the possession of astronomers well ahead of the time when the event would occur. What was the best use that could be made of them? A total eclipse of the sun is chiefly important because it is only then that that wonderful fringe of light surrounding the sun and known as the "corona" can be seen. In the last few years a new significance has been added on account of one test of the Einstein theory which can only be made at such a time. But there was another factor in the situation which seemed to demand consideration. A striking natural phenomenon is no longer an event to be regarded with fear and trembling. A certain degree of education has reached the mass of the people and here an opportunity to teach the ways of science to multitudes at one time was presented in such a fashion that it could be utilized for further instruction. It is doubtful if any previous eclipse has been visible over such a thickly populated area, but it is quite certain that none has ever been seen by so many millions capable of understanding the meaning of the phenomenon.

A further question arose. Could observations of value to astronomy be made by those unaccustomed to observe and without special equipment? If so, the educational value of the event would be greatly increased by the preparations which many would make. They would try to find out what to look for, where to go, and what to do. The added interest created by a share in the observational work would be great.

The astronomers of America, like scientific men in every civilized country, are members of an association devoted to furthering the interests of their subject, known as the American Astronomical Society. This body meets once or twice a year in order to tell and learn of the progress that has been made and to discuss various astronomical problems. Whenever an important eclipse is to occur, a committee is appointed to coördinate all activities in connection with it. This committee is in no sense a governing body to dictate what shall be done; it is merely a gathering point for information and discussion, so that the most effective results

may be obtained. When the time came to appoint the committee for the 1925 eclipse the society felt that something more should be done than merely to secure the best results for astronomy. In view of the general public interest in the subject, the spectacular character of the event, and the fact that it could be seen by many millions without leaving their abodes, a sub-committee was formed which had the special duty of seeing that the public should be given accurate and full information concerning the event. Since the writer, who was the chairman of this sub-committee (the "sub" was usually dropped for the sake of brevity), was a member of the staff of Yale University, its activities naturally centred in New Haven.

Much astronomical work now-a-days is done by observations in large masses. The difficulties of making some of these observations are so great that it is only by taking very large numbers of them and averaging the results anything new can be learned. The society considered whether a similar idea might not be used with respect to the millions who would see the eclipse. Was there not some observation which an ordinarily intelligent person without special equipment or special knowledge might make? And by thousands of such observations could not results be deduced which would help to advance the science? It concluded that not only could this be done, but that there were various sides which could be taken up by more highly trained people who had, however, no specialized knowledge in astronomy. It therefore added to the words "public information," which gave the first duty of the committee, the words "and coöperation." A certain further duty was laid on this committee. The observations which the public were asked to make would, if successful, assist in determining with great accuracy the position of the moon at the time of the eclipse. In order to make the best use of this position, it was necessary to observe the moon for at least a month before and a month after the event, so that its path might be laid down with the greatest possible accuracy during that time. A campaign was therefore undertaken to ask observatories all over the world to make such observations.

The idea of obtaining the interest and coöperation of the public was not altogether new. It had been proposed and discussed, at least in private, on other occasions of a similar character. But, as far as the writer knows, this was the first time that a

determined campaign had been started by a body of scientific men to interest the people in a scientific event, to describe it in language which could be understood by everyone, to explain what might be seen and how best to see it, to secure the coöperation of various public services to attain these ends and to assist in the purely scientific investigations, and generally, to attempt to reach, not only those who would naturally be interested, but also the great mass of the people who rarely have the work of the scientific world brought home to them in a manner which shall leave a lasting impression.

That the educational value of such a campaign, if successfully carried out, would be very considerable was obvious at the outset. Ignorance and its constant attendant, superstition, still exist to a considerable extent in spite of the determined efforts which have been made to ensure some degree of education for everyone. With this larger issue went the creation of a more general interest in astronomy and the advantages to be gained therefrom, which astronomers recognized as a legitimate outcome; they would have been more than human if they had not done so.

COÖPERATION.

Public interest was fully aroused at least a month before the eclipse. It then became possible to see what help could be obtained from the various public services. These organizations now-a-days have a quite different relation to the public from that which was common before the opening of the present century. Then they issued their decisions and, although the public and the press might pour forth thunderbolts, they usually had their own way. Now they frankly admit that any action taken must have at least a considerable degree of public opinion in its favor. It was an excellent sign of the general attitude towards the eclipse that no suggestion of action made to any one of these services was thrown down. All that seemed to be needed was for them to be shown the way in which they could assist.

Mention has already been made of the Nautical Almanac Office of the Naval Observatory. Its natural interest in the eclipse, the predictions of which it furnished, in detail where requested, soon took a wider sweep. Through the coöperation of Captain Pollock, the Superintendent of the Observatory, the use of the dirigible *Los Angeles,* to carry a party of astronomers

from the observatory a mile or so into the air in order to make observations, was secured. In the event of cloudy weather over the whole of the land track of the shadow, it might be still possible to secure records of the eclipse from the platform of the airship. And in any case, it would be valuable as an experiment for future guidance, to find out what observations could be effectively secured in this way, since no such previous attempt had been made. The Army also contributed by sending up an airplane. Observation here was obviously more difficult on account of the rapid oscillations which are inseparable from its motion. On the other hand, the airplane can rise without difficulty three or four miles into the air and thus give a better chance of getting above the clouds.

The timing of an eclipse is a matter of great importance to those who are interested in the motion of the moon. Its occurrence is predicted to a second and now-a-days it is not expected that there will be more than a very few seconds between the prediction and the observation. For the latter every observer must have the correct time. Since the advent of wireless, few observatories feel that it is necessary to get the time directly from the stars and sun. The Naval Observatory is especially equipped for this work and it is an essential part of its daily routine. The big wireless stations at Arlington and Annapolis daily transmit this direct from the observatory to every one who wishes to tune in, and their error is rarely more than one or two-tenths of a second of time. For the eclipse these stations agreed to send out the correct time by wireless signals half an hour before and half an hour after totality. This would enable observers to correct their watches and clocks both before and after, allowing them also to judge whether their timepieces had run properly during the hour.

For the all-important question of the weather at the time of the eclipse, the bureau at Washington agreed to issue a special forecast on the previous afternoon to be sent out by telegram and radio. It is not yet possible to predict the condition of the atmosphere with any certainty much more than thirty-six hours ahead, in spite of the claims often made by various amateur weather prophets. The human mind has a curious faculty for remembering successes and forgetting failures, and it is also apt to interpret any resemblance as a success, if belief tends in that

direction. It is fairly safe to predict a certain number of storms during the winter, and if the prediction covers a range of two or three days, as is often the case, almost any weather that we are apt to have in winter can be fitted in by the willing believer. The astronomer knows this so well that the only matter on which he will ask for information in the months before any eclipse when he must begin to make his preparations is the average weather for the date and place in past years. This is easily obtained from the records of the Weather Bureau. At the time of the eclipse, these averages showed that the chances for clear weather at New Haven were about even and that they diminished towards the western part of the track.

The special forecast issued on the afternoon before the eclipse was made from observations taken not later than eight o'clock that morning. It predicted almost exactly what actually happened, namely, clear skies on the eastern part of the track of the shadow with clouds over most of the western part. While of course any prediction could not affect the preparations of the astronomer who must be fully ready to do his work once he has decided to observe, it was of very considerable importance to the tens of thousands who were intending to travel into the shadow track and to the millions who expected to postpone their daily activities in order to see the spectacle. The electric power companies also had to be prepared. If the skies were cloudy, the factories would continue running, and a heavy additional load would be placed on their services by the need for artificial light for a short time. Numerous arrangements which had been made for special trains would have to be cancelled. On the other hand, if the weather were clear, it had become sufficiently evident at that time that the consumption of current for both light and power would drop to a minimum in most places.

Another department of the federal government, the Hydrographic Office, issued a special map of the Atlantic showing the eclipse track and giving a brief but sufficient account of the observations which could be made at sea. This was distributed in advance to all vessels which might be in or near the track at the time of the eclipse and thus furnished another possibility to secure a record.

All through the work of giving publicity to the eclipse,

emphasis had been placed on the conditions necessary to see the spectacle at its best. These were summed up in the phrase: "No lights, no traffic, and no noise." Everyone knows how the glare from automobile headlights or street lights or even from brilliantly lighted windows destroys the beauty of an upward gaze on a moonlight night, so that the delicate coloring of earth and sky and the fainter streamers of the corona would be altogether lost under such conditions. During a total eclipse the general darkness is usually that of a moonlight night, and it is then scarcely safe to operate traffic on the roads without artificial light. Both on account of the safety of the public and the opportunity to observe the eclipse, it was asked that as far as possible all traffic should cease during totality. The initial impulse to secure general observance of these suggestions was obtained when the Connecticut Company, which controls nearly all the trolley car systems throughout the state, issued instructions to its drivers to stop their cars as soon as it became unsafe to operate without headlights.

The astronomical work asked of the public was mainly the determination of the northern and southern boundaries of the shadow. When the skies are clear it is possible for even an untrained person to say whether the eclipse was total or not at the particular place where he stood. This can be done by various tests. In order to obtain the information the following set of questions to be answered was widely circulated through the newspapers and every available agency:

QUESTION 1. *If the sun is not quite eclipsed at your station there will always be a bright edge of the sun visible, or perhaps only a single point. One bright point may appear on one edge of the sun before the other has entirely disappeared. At your station was there any time at which no bright edge of the sun was visible? Answer YES or NO.....*

QUESTION 2. *If the bright edge of the sun entirely disappeared, how many seconds elapsed before another bright part of the sun became visible? Answer ..... seconds.*

QUESTION 3. *Was the time set down in the last question merely guessed at or was it actually measured? If measured, how was the measurement made?*

.....

QUESTION 4. *The fringe of light surrounding the sun and called the corona is fully visible only if the face of the sun is entirely covered. At your station was there any time at which you could see the corona* all *around the sun? Answer YES or NO .....*

QUESTION 5. *Could you see any stars or planets at the time the sun was most completely covered and how many did you see?*

.....

(If convenient, draw a little map showing the position in the sky of the eclipsed sun and of the stars and planets that you saw.)

QUESTION 6. *If you are on a high building or a hill near the edge of the shadow path you may be able to see the shadow advancing across the country. If so, what buildings or other landmarks were inside and what were outside the edge of the shadow?* .....

Landmarks inside of the shadow:.....

.....

Landmarks outside the shadow:.....

.....

QUESTION 7. *It is necessary to locate your position very accurately, so that the engineers who compute the reports will know just where to place your observations on the map. Accordingly, give your position by means of the nearest street intersection (if in a city or town) or by means of some easily located building such as a railroad station, a town hall, or some landmark which can be placed easily on a map by a person familiar with the district*

.....

If you have a map of your district, published in a newspaper or from any other source, mark a cross on the map at the position where you stood and send in the map with your report.

Other requests to the public included the photography of the corona and observations of the intensity of the light during totality by means of the ability to read types of various sizes and to detect known features of the landscape. Somewhat more technical instructions were needed to obtain details concerning the shadow bands.

The results give some information concerning the methods which are useful in a campaign of this character. Where definite questions are asked in a manner which can be easily understood and are circulated in such a way that they reach those for whom they are intended, as in the case of the questionnaires for the determination of the edge of the shadow and for the investigation of radio strength, large numbers of answers come in and a considerable proportion of them can be utilized in discussions of the results. Where equipment, like a camera or a radio set, is widely distributed, it will be extensively used, even without special advertising effort, and the results will be improved by press articles giving general instructions. Where neither of these aids is present, the material is scanty and of doubtful value.

JANUARY 24, 1925.

The bitter cold of the day preceding the eclipse seemed to have no effect on the general enthusiasm. At night the stars were shining brilliantly with the thermometer near zero everywhere. As the first faint streaks of dawn began to show in the sky, clouds gathered in the east and west so that by seven o'clock it looked as if the sun might be hidden after all. An hour later, when the first little nick appeared in the edge of the sun low down on the horizon, it was evident that the thin blanket was slowly dissolving. Would it go in time to leave a clear view of the sun? By nine o'clock, when a narrow crescent only of the sun was still visible at New Haven, it was evident that this city at any rate was to enjoy the spectacle. A thin wisp of cloud still lingered as a threat near the sun, but anxious watchers saw that it was moving away or dispersing and all knew that nothing was to mar the spectacle.

From early morning thousands had been making their way by automobile, trolley, and on foot over snow-covered roads to reach hills from which the onrush of the shadow might be seen. Others, perhaps wiser if less adventurous, made their way to hospitable residences from which good views could be obtained and where shelter and hot coffee were available. Many stayed at home or journeyed to their usual employments, secure in the knowledge that a warning signal would be given in time for them to reach a chosen roof or open space. Many hundreds were gathered on the open roads and ground near the observatory, whence a view could be obtained and from which access to see the instruments would be easy after the event. In New Haven, and the writer learns that conditions in other parts of the state were similar, the factory whistles blew at six minutes past nine. Banks closed their doors, factories and offices stopped work, the streets became quiet, lights disappeared, and all who had not already reached their vantage points went quickly to roof or open space. Most of the people had provided themselves with smoked glass or a card with a darkened photographic film so that the approach of totality might be viewed without danger to the eyes. These had been sold or given away by the tens of thousands and even so the supply failed to meet the demand.

A minute or so later the shadow bands began to dance in streaks or wavy lines across the snow-covered ground. By this

time the sun was merely a thin crescent, and the little cloud near it added its part to the spectacle by showing bands of rainbow colors.

Suddenly at fifty-three seconds after eleven minutes past nine the crescent broke in pieces and one second later disappeared. The event occurred five or six seconds after the prediction, though no one but the astronomers knew that, nor if they had known would it have mattered. Those on the hills watching for the onrush of the shadow from the west failed to get a sight of it, but that was soon forgotten in the sight of the glory of the corona which burst into view. From behind the black disc of the moon, streams of pearly white light shot out in all directions. The eye, now needing no protection, could trace them one or more breadths of the disc away until they were lost in the dark blue sky. Not far away, Jupiter, Venus, and Mercury shone brilliantly, and the brighter stars were visible. The horizon in every direction showed the yellows and pinks of dawn, while high in the sky to the southwest appeared the faint edge of the band of shadow fifty miles or more away.

Close to the edge of the sun could be detected the flame-like wisps of red light known as the prominences. These were difficult to detect with the naked eye, but could be easily seen through a pair of binoculars. One of them shows on the photographs as a faint arch some forty thousand miles high. Another gave the appearance of a clearly defined peg on the disc as if the gas had suddenly rushed out and had not had time to disperse.

A brief two minutes and a bright spot of light appeared, immediately followed by others, which almost in an instant joined up and formed a crescent. The corona faded out, the snow-covered ground quickly grew bright, and the great climax had passed. For a few minutes longer the crowds gazed at the growing crescent and then coming back to earth remembered the chill of the air and sought warmth and shelter. Soon the hum of machinery was again heard, the banks and stores opened their doors and the daily round flowed on. But business and manufacture languished. It was in any case only a half-day and many experiences had to be interchanged. A whole state and surrounding people in the heart of the nation's business cannot stop work for half an hour to see the event of the century and resume as if nothing had happened. For once, science had come into its

own and concentrated attention on itself to the exclusion of everything else. Ten million people had stopped to gaze into the sky and saw together the glory of the heavens.

The attempt to set forth the many human incidents which occurred would almost fill a chapter, even those which have reached the writer. How the prevalent disbelief amongst the less educated portions of the masses that anyone could foretell the future with such accuracy was changed to wonder, was illustrated many times over. If at the present moment it were reported that any astronomer known to the public had predicted a calamity such as an earthquake, there would probably be universal panic. The keen sense of responsibility of the press has fortunately avoided any such occurrence. Some two weeks after the eclipse a small and ignorant group of religious enthusiasts predicted the end of the world. The press featured it in a semi-humorous fashion, but it was after all a striking object lesson, illustrating to many the difference between the scientific man, sure of his ground based on the solid rock of past experience, and the human mind with no furniture but its own ideas to guide it. After all, fear is chiefly the child of ignorance. Science claims no control over the forces of nature. It can only claim knowledge, and by that light show humanity how to act.

ASTRONOMERS AT WORK.

When the track and time of the eclipse were first announced, few of the observatories felt inclined to make many preparations for taking extensive observations. Undertaking an eclipse programme is usually an expensive procedure, requiring weeks or months of preparation during which the regular work of the observatory is seriously handicapped. The eclipse did not seem very promising for securing new information since the sun at best was rather low down in the sky and the chances for fine weather did not exceed 50 per cent. Gradually, however, the feeling grew that as the eclipse track presented so many unusual facilities for observation the opportunity should not be lost. The observatories of Yale, Wesleyan, Vassar and Cornell would be well within the complete shadow and were equipped to make extensive observations or to furnish facilities to visitors from other observatories. Smaller stations like that of the Maria Mitchell Observatory on Nantucket and many private instruments

were also well situated for observation. In the end a number of parties came into the zone from other parts of the country, the majority of them accepting the hospitality of the observatories at New Haven or Middletown as furnishing the bast chances for success.

The Yale University Observatory in New Haven had the extraordinary good fortune to be situated within half a mile of the predicted central line of totality, and thus to secure the longest duration of totality possible for its longitude, namely, two minutes and one second. It had a record for clear skies on the day and hour of the eclipse based on averages for that period in previous years better than any other place within the whole track, namely, about 50 per cent. Its grounds cover some seven acres on a ridge a hundred feet or so above, and less than a mile and a half from, the centre of the city and are easily approached from any direction. There are no buildings in its immediate vicinity high enough to interfere with its view in any direction. It is true that the great Winchester Arms factory is less than half a mile away, but its chimneys and towers stand on much lower ground and lie directly to the west of the observatory while the sun at the time of the eclipse was in the southeast. Even had there been danger of trouble from smoke flowing across and interfering with the work of the observers, it would at least have been absent that morning because the management decided to shut down for the week on the previous Friday evening so as to give its employees a chance to see the eclipse. Incidentally it may be mentioned that the notice posted on its bulletin board announcing the shut-down also gave an excellent summary of the principal events of the spectacle, a procedure which was not only in line with the efforts which were being made to secure the best educational results from the phenomenon, but is indicative of the modern spirit of factory owners towards the intellectual welfare of their workers.

Astronomy, the "Geography of the Heavens" as one old text-book naïvely calls it, was one of the regular subjects in the curriculum of a century ago. It was treated mainly as a descriptive science and much of it must have been rather uninspiring since it had little more to give than illustrations of geometry and mathematics. The calculation of an eclipse is within the memory of many still living as a portion of their college work in astron-

omy. Even for the expert astronomer the subject was mainly confined to the motions of the bodies in our solar system and the description of what could be seen through the telescope. Speculations and theories concerning the development of our solar and stellar systems were widespread, but they had little basis until the application of spectrum analysis began to give information as to the nature of the materials composing the sun and the stars. Then photography, which permitted the leisurely study of phenomena instead of the fleeting glances obtained through the telescope, extended the range of knowledge and made possible the testing of theories and the construction of an edifice which embraces the fundamental sciences of physics and chemistry and demands for its continuance all the resources which the mathematician can furnish.

OBSERVING AN ECLIPSE.

The ordinary telescope in an observatory is so mounted that it can be directed to any part of the sky, and when it has been pointed at any object, it must stay pointed. The daily motion of the earth round its axis causes every object in the sky to appear to move when looked at through a fixed telescope, but all important instruments are driven by a "clock" which is so timed that the object will always remain at the same spot in the field of view. By this device, whether an object is to be observed with the eye or by means of the photographic plate, its rays can be made to stay within the tube of the telescope.

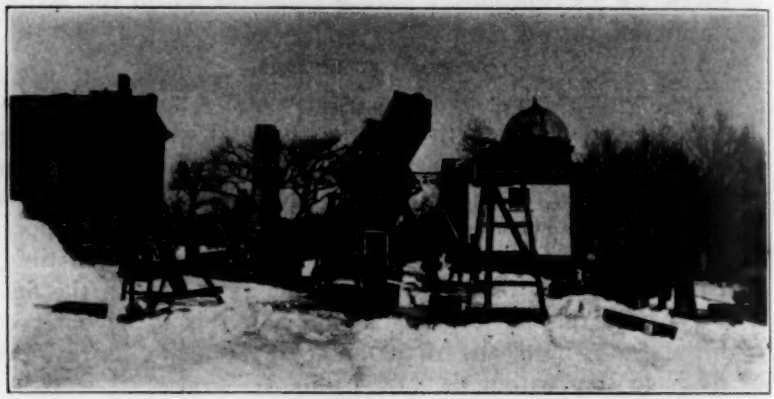
When the magnification of the object is slight and the time of exposure short, it is not necessary to keep the telescope in motion. But, for some of the work, as much magnification as possible is desired and the greater this is to be, the longer must be the tube of the instrument. The time of exposure required increases with the magnification but can be diminished by using big lenses or mirrors which will gather in more light.

At an eclipse a large image and the shortest possible time of exposure are desired by the astronomer. With the large image the motion becomes visible. On the other hand, the whole amount of motion during the few minutes of an eclipse is small. Instead of building a long movable telescope—an expensive procedure—the eclipse observer erects a fixed temporary tube, generally of wood, pointed in the direction the sun will have at the time. The lens or "object glass" is mounted in a fixed position at its upper

end, and, to take care of the motion, the slide carrying the photographic plate at the other end is moved by the "clock" so that the image of the sun on it will stay in the same spot. Of course if, for any purpose, only a short tube is required, this is often mounted so as to be moved by a clock, but as the motion required is very small, the mechanical arrangement can be much simplified. Both devices are used at an eclipse.

As far as the observatories situated in the zone of totality were concerned, their telescopes with the driving apparatus could be used without any new construction. But since many different kinds of observations requiring different instruments are made

FIG. 1.



Instruments to observe the eclipse on the grounds of the Yale Observatory. (Photo by Lewis Bose.)

during an eclipse, these different instruments could be mounted on the regular telescope tubes. The big instrument at Middletown with its object glass of twenty inches in diameter had half a dozen extra pieces of apparatus attached to its tube, all of which were in action during the eclipse. The old heliometer at New Haven, now a relic of the past, carried a moving picture camera which ground out its film all through the eclipse.

The grounds of the Yale University Observatory presented a regular battery to the sun. Prof. J. A. Miller, of Swarthmore, who has a large equipment for eclipse work which he has taken to several of these events in different parts of the world, brought it to New Haven and erected it in the open. With him was associated Dr. H. D. Curtis, of the Allegheny Observatory. The

most picturesque feature was a wooden tube over sixty feet long. Its upper end was supported on a trestle and carried a twelve-inch lens, while its lower end, with the photographic plate holders and

FIG. 2.

The pendulum camera. (Photo by Lewis Bose.)

the clock, was situated in a wooden hut. Besides this, three polar axes, each supporting a movable tube with its own clock, were erected and carried different instruments, including two movie cameras operated by a news company. Other pieces of apparatus of a less pretentious character were in evidence, including a

telescope erected by the Reverend D. B. Marsh, who brought it from Bermuda.

The Yale Observatory of course had its ordinary equipment at work. The Loomis telescope with its fifty-foot tube was taking pictures, not only during totality, but also before and after for the partial phases, so as to secure plates which might furnish additional material for determining the position of the moon. The new Catalogue Camera and a doublet attached to the Reed telescope were used to obtain photographs of the corona. On the grounds, one of the meteor lenses was mounted with some twenty-five feet of film, an exposure being made every second by means of a pendulum, from a short time before totality until the sun's edge became again visible.

In order to work all these instruments as rapidly as possible, many assistants were drafted in to help and were trained by means of many rehearsals in their duties. Labor is cheap on these occasions. As much division of the work as is possible in the space round each instrument is made, so that the duties of any one individual are few and clear cut. Most of the exposure times are short, the chief delay being in the changing of the plates. Altogether some fifty persons were on the grounds occupied in various ways, no others being admitted until the eclipse was over.

A considerable amount of work was done in the Sloane Physics Laboratory of the University in connection with the electrical conditions of the atmosphere. Observations of its ionization and effects on the earth's magnetism were made. In connection with wireless, a complete record was kept of the radio strength during the whole of the eclipse. In order that this should be exactly correlated with the time, the American Telephone and Telegraph Company connected, without charge, the laboratory with the observatory by a special wire which automatically carried the second beats from the clock to the observers.

At Middletown numerous observations of many kinds were made. The big telescope with its lens of twenty inches diameter took four photographs during totality and others during the partial phases, and its four-inch finder took additional pictures. The University of Virginia had two spectrographs mounted for obtaining the spectrum of the corona as well as an instrument in another part of the building for photographing the flash. The observatories of the Universities of Wisconsin and Illinois had

devices at one of the windows of the building to measure the intensity of the light of the corona. On the roof, Brown University was busy obtaining pictures of the corona.

In an adjoining garage, the Harvard Students Observatory and the Bureau of Standards had special instruments for measuring the intensity of the coronal radiations and tried to photograph the shadow bands. In the physics building of the University was a party from the Mount Wilson Solar Observatory in California which brought a reflector of twenty inches in diameter and other material designed to obtain the flash spectrum, the coronal radiations and direct photographs of the streamers.

On other roofs were observers connected with other departments of Wesleyan University as well as parties from Williams College and the Weather Bureau. These were taking observations connected with our atmosphere, a moving picture machine being used to photograph the shadow bands.

Professor Miller had been on the grounds of the Yale Observatory at intervals during the previous weeks attending to the erection of his instruments and making the observations necessary for their careful adjustment. The week of the eclipse, a period with bitter cold weather and for one day experiencing a heavy snowstorm, was a time of intense activity on the part of everyone. In a New England winter much must be done at the end, for storms are not infrequent. As to the prospects of the weather, it is all or nothing; no half-measures are of much value. The day before, one of the coldest of the winter when the thermometer stood most of the time near zero with a wind blowing strongly, constant rehearsals took place, to the delight of the press correspondents and camera men who were then able to get the material which they would be denied the following morning, for none were to be present during the eclipse. What time was not used in this way was fully occupied in talking—for publication and otherwise—because this eclipse had ceased to be the private property of the astronomers. The general instructions were to tell all you know and, after doing so, to sacrifice your friends and colleagues without compunction to the demands of the press. The gate to heaven, so far as it was under the control of science, was thrown open.

The last and perhaps the most interesting rehearsal took place between seven and eight in the evening, when, for the first time,

the observatories at New Haven, Middletown, Poughkeepsie, and Ithaca and observers at stations in Buffalo, New York, and Easthampton, Long Island, were connected up by telephone and telegraph. The arrangements were such that intercommunication by telegraph was complete for every station, but only the Buffalo, Poughkeepsie, Ithaca, and New Haven stations could talk, the remaining stations, however, learning all that was said. As stated above, this service was furnished without charge by the American Telephone and Telegraph Company. The organization was remarkably complete. Three wires had been run from the nearest trunk lines into the observatories and stations for telephone, telegraph, and reserve, respectively. At each place, telephone and telegraph operators, a circuit expert, and the local construction chief were on hand, to get the whole system in working order and then to use it as instructed by the local astronomer. Full directions, contained in a typed pamphlet of some eight long pages, had been issued after consultation between the leading officials of the company, Dr. E. E. Free, and the writer.

The Harvard College Observatory had planned observations at several stations, one of them, at Buffalo, being occupied by Dr. Harlow Shapley, the director. The company furnished him with an excellent post on the top of the Exchange Building, the signalling instruments and operators being with him there. At Easthampton, Doctor Free had gathered a corps of radio experts, moving picture operators, and other observers. The New York station was in the Laboratory of the Western Electric Company and signals were recorded on its extremely delicate mechanisms. Professor Boothroyd, of the Cornell Observatory, and Professor Furness, of the Vassar Observatory, took charge at Ithaca and Poughkeepsie, while Mr. H. Clyde Snook, head of the Western Electric Research Laboratory, took charge at New Haven at the request of the acting director, who had been made the responsible chief for all stations. At the conclusion of the rehearsals all connections with the trunk lines were left undisturbed until after the eclipse.

On Saturday, the whole system was in working order and complete intercommunication established by 8.30. From 8.40 to 8.45 it was silent, while the Arlington and Annapolis time signals were being sent by telegraph and radio. The period from then till nine o'clock was utilized in sending and receiving mes-

sages concerning weather and other conditions at the various stations, the wires being kept fully in use so that any failures should be instantly detected. At 9.05, ticks at intervals of a second were sent by telegraph and telephone until a few seconds before totality. A short silence and the first message of the totality was received from Doctor Shapley. Actually what he said indicated cloudy weather with no information, but it was accidentally interpreted as the expected signal. By good fortune this came at the exact second when totality must have occurred there and indicated that the eclipse was five seconds late. Immediately after, the Ithaca operator began sending ticks until near totality when, after a brief silence, the signal for second contact indicated that the eclipse was five seconds late. Poughkeepsie followed, making the interval between prediction and observation three seconds. The final signal came from New Haven where the estimate was five seconds. The remaining stations recorded their estimates but they were not sent over the wires since they were not needed, once the eclipse had started at the more westerly points.

Friday night was clear and cold. The lonely watcher in the observatory, rising from his cot from time to time, saw a snow-covered ground lit only by the stars and a few nearby lights, with no hint of anything but a glorious day for the morrow. At 5 A.M. he might have been seen working in the open at a last adjustment of his instrument with a tiny flashlight which threatened extinction at any moment. A hint of dawn appeared in the east and with it some wisps of cloud. The rising sun disclosed gathering cirrus both to the east and west, and confidence changed to anxiety. Soon the observers began to gather, discussion of the weather on every lip. Those arriving on foot and in cars were challenged to show their tickets of admission, distributed with many precautions the day before; no relaxation of the rule was permitted.

Shortly after eight the first nick in the edge of the sun was seen through the now diminishing wisps of cloud. Eye protectors came into use and cameras began to click. The motion picture operators set their instruments going to take a picture every second or so. Every observer began to give a last glance to his instrument, however confident he was that everything was right and ready. About 8.30, the boy scouts arrived, useful as always

for voluntary service, and formed a protecting line for the observers around the half-mile boundary of the grounds, reinforced by some half-dozen or more guardians of the peace assigned by the chief of police for this service. Their duty was also to ask that traffic and lights and noise near the observatory should be avoided during totality, and, with the coöperation of the people, nothing occurred to mar the spectacle or to trouble the observers.

The clouds had vanished as if by magic and none remained but one small thin wisp ten degrees or so from the sun, apparently stationary and serving, partly as a reminder that the air still held control of the situation, and partly as a setting on which the eye might rest. The last rays of the sun shining through the tiny particles of water vapor were broken up into colored beams and the cloud was lighted as if by a rainbow with its spectral order several times repeated.

By nine o'clock all was ready. At precisely six minutes past, the factory whistles gave their warning blast. The curious shadow bands began to show their fleet alternations of light and shade travelling quickly across the snow. A few observers began to measure their direction and speed by placing sticks on the ground or by other devices, and some of the bolder photographers attempted to catch them on their films. A minute later, a megaphone boomed out to the observers, "Buffalo says five seconds late." The counter, with his eye on a chronometer, calls, "Four minutes more." Again the megaphone, "Ithaca says five seconds late." A minute later, "Poughkeepsie says three seconds late." The counter makes a rapid calculation, and averaging at four seconds late, calls out: "One minute . . . thirty seconds . . . fifteen . . . ten . . . five, four, three, two, one"; and "Go," from the observer watching for the "flash" spectrum seen one second or less before totality.

On the grounds of the observatory nothing was heard but the hard voice of the counter, tolling out the seconds from beginning to end, the click of the cameras, and a hurried whisper here and there. Only an occasional rapid glance at the sky could be permitted if every second was to be used. Finally, at the one hundred and twenty-first count, a shaft of light burst forth and the event was over. A sigh of relief comes from every mouth as the labor of months has been crowned with success. Plate holders and films are carefully wrapped and conveyed out of the

way of harm, and in a few minutes everyone is at ease. Three blows of the whistle and the protecting lines are broken. The scouts continue their duties by forming details to guard the instruments from the too curious, an unnecessary precaution as it turned out, for the visitors were far too much impressed with the magic of the craft to venture any such attempt. Amongst the first were a body of twenty or more reporters who gathered at once in an unheated room, the only one available for the purpose, and with shivering fingers attempted to write the information at once given out so far as it was known on the ground and by telegraph over the special circuit. One motion picture news operator rushed his film by special automobile to catch the 9.45 train and his picture was exhibited that night in New York City and the next afternoon in Chicago.

Taken as a whole, the eclipse was a success from the point of view of the astronomer. The inevitable failures here and there, through some misunderstanding or forgetfulness, occurred, but they were not numerous and in no case did they cause the loss of observation of any essential part of the phenomenon. If one observer failed at one point some other had the record.

PREDICTING AN ECLIPSE.

The accurate prediction of an eclipse always strikes the layman as one of the most wonderful achievements of astronomy and perhaps this is true. It is not, however, the work of any one man or of any one time in our history, but an edifice gradually built up by observation and theory over at least four thousand years. Each step forward produced a closer agreement between the forecast and its fulfillment, until now the path of the shadow on the earth can be laid down within a mile and the time of totality within a few seconds. In the future we should be able to improve on this.

The earliest known predictions are those of the Chaldeans made some four thousand years ago. They must have watched eclipses of the moon and sun for hundreds of years and kept records on their tablets during that time to have learnt that there is a cycle which very nearly repeats itself every eighteen years. This cycle, which is known as the Saros, indicates that any eclipse known to have occurred will be followed by a similar eclipse eighteen years later. In the case of a solar eclipse, however, the shadow track is considerably shifted on the earth so

that in its new position it will not give a total eclipse at the same places as before. Later races learnt more. But the great step forward was the work of Isaac Newton, who proved that the simple law of gravitation mainly controlled the movements of the sun, earth, moon, and planets. During the two and a half centuries since he announced it, mathematicians and astronomers have labored hard to follow out the consequences of this law, until by observation and calculation they have succeeded in building up a set of mathematical expressions from which the position of any of these bodies in the sky can be obtained at any time in the past or future.

The people who do the actual calculation do not need now to have much more knowledge of mathematics than is given in the college freshman year. What they have to do is mainly to extract numbers out of big volumes of figures, "tables" as they are called, and to add them together. The rules for finding these numbers from the tables are made so simple that the calculator only needs to follow them in order to get the results needed. The position of the moon is predicted in advance for every hour throughout each year and this work occupies one person for about a year, so that he or she can just keep ahead of the game. For an eclipse, more work is needed, but this again has all been carefully laid out in the same way.

The Nautical Almanac Offices of the various countries take this calculating work in hand and make the predictions, sharing the different parts of the work so as to avoid duplication. The British office gets out the positions of the moon and sun and the Washington office, using these, takes in hand the eclipses. In the years previous to 1923 the predicted times were often fifteen or twenty seconds wrong. At the California eclipse of that year, the first with a new set of tables for the moon, there seemed to be no error, and in 1925 the small difference of some four or five seconds is being carefully investigated and its source traced, so that with future eclipses the error may be made even less. The difficulty is not now with the law of gravitation but one of another kind. Some unknown force acts on the moon to make it deviate a little and until we can find out more about this unknown force we cannot predict the deviations. The sun is affected in a similar way, but to a much smaller extent. It was partly for the purpose of finding more about these deviations that the campaign to

observe the moon during the months before and after the eclipse was inaugurated, and the results, combined with those obtained at the time of the eclipse, may furnish valuable information.

SCIENTIFIC RESULTS.

It is as yet too early to give very complete information as to the additions to our knowledge of astronomy obtained from observation of the eclipse. Photographs will require some months for measurement and study, while the information to be obtained from the hundreds of answers obtained from the questionnaires has to be carefully plotted on maps and coördinated. But certain results have already appeared from a preliminary survey of the material, and, with the understanding that the conclusions stated here are not final, some account of them may be given.

The positions of the northern and southern edges of the shadow were to be determined in three ways: First, through direct observation by hundreds of observers who were able to say whether the eclipse was total at the particular spots from which they looked at the sun. While there will be many poor judgments of the event, average lines can be drawn which will represent the balance of evidence. At present, the indications are that the southern line was about a mile to the north of that predicted, while the northern line was perhaps only half that amount wrong.

The second method was for observers on high buildings or hills to look for the shadow and watch its limiting position as the edge passed to the south or the north. This particular form of record failed for the same reason that the onrush of the edge of the shadow was nowhere seen with any certainty over the whole band of totality. An explanation was soon forthcoming. Although the sky appeared clear to those on the earth, the airmen looking down on it from above, and particularly Dr. W. J. Luyten, of Harvard Observatory, who was some 16,000 feet aloft in an airplane sent up by the *New York Times,* reported that the whole earth seemed to be covered by a haze, and at the time he wondered if we should see the corona. This haze, though not thick enough to prevent a good view of the sun, was sufficient to scatter the light at the edge of the shadow and prevent it from being seen as a sharp line. Another sign of it was a view from New Haven of the southern edge of the shadow where it struck

the upper atmosphere thirty or forty miles away. This was visible to a few careful observers but was so ill defined in the sky that few noticed it.

The third method is a very sensitive one, namely, by observations of the time that totality lasted by observers situated within two or three miles of the edges. Many persons used a stop-watch or clock for this purpose and obtained the duration of the total eclipse with a maximum error of one second of time, which at such a position would give the location of the edge within a quarter of a mile if the edge of the moon were uniformly circular. If, however, there were a valley on the moon at the place where the edges of the moon and sun came into contact when totality began or ended, it would tend to shorten the time of the duration. Similarly, high ground at either of these places would tend to lengthen it. These valleys and hills, however, can probably be allowed for by examining maps of the moon. In any case, the observations add to our knowledge.

Information concerning the positions of these edges of the shadow can be used in two ways. The distance between the two edges depends on the diameters of the sun and moon and also on the distances of these bodies. What we are mainly concerned with at the time of an eclipse is, however, the apparent diameter of each, that is the size it appears to be to a person on the earth. The apparent size depends on the ratio of the diameter to the distance, and this is one of the main factors which gives the width of the shadow band at all eclipses. The distances of the bodies from the earth at different eclipses vary, but the variations are known with such accuracy that they can always be fully taken into account. The knowledge which may be gained by the exact determination of the distance between two edges will tell us whether the predictions of the width of the shadow band on the earth at future eclipses should be increased or diminished. The present indication seems to be that it should be slightly diminished.

The second source of information is derived from the position of the central line of the shadow band, which may be taken to be half-way between the northern and southern edges. The more exact knowledge of this line gives information as to the positions of the centres of the sun and moon at the time of the eclipse. The addition here is chiefly to our knowledge of the motion of the moon, especially at the times when the sun and moon are

near together, since at such a time it is always difficult to observe the moon accurately.

The actual times at which the eclipse began or ended are needed with greater accuracy than is usually possible for anyone to obtain unless he is a trained astronomer. These were mainly left to the principal observatories in the shadow path to determine. The predictions, furnished in the first instance by the Nautical Almanac Office in Washington and in some cases tested at the observatories, were compared with the observations, and all showed that the eclipse was some few seconds late. The determinations received at the time of writing are as follows—with the number of seconds late in each case:

Ithaca	5.2
Poughkeepsie	3.3
New Haven (3 records, average)	6.0
Middletown	3.6
Easthampton, L. I.	6.6
Nantucket	4.9

The differences between these different determinations are probably due mainly to the ragged edge of the moon, in much the same way as that explained in the case of the duration at the edges of the shadow. The average of them all—about five seconds—may be regarded as the error of the prediction which needs explanation.

As explained above, the correct prediction of an eclipse depends on our knowledge of many facts, some of which are better known than others. One of these is the position of the sun in the sky at any time. Usually it follows the predicted place very closely and when it does get away from it, the change is quite slow and regular. During the months before and following the eclipse the observations of the sun show that it had run ahead of the place predicted from the tables by about one second of arc. Small as this angle is, it is sufficient to account for two of the five seconds. A second factor is the position of the moon. This body, while it appears to deviate in a short period of time but little more than the sun, does so much more irregularly, and, though we have some knowledge of its motion near the time of the eclipse, this knowledge is not at the present moment sufficient to say whether it was ahead of or behind its schedule. We shall

know more at a future date when the results of the campaign for its observation all over the world are available.

The other two factors in the situation about which there is doubt are the diameters of the sun and moon. It has already been mentioned that the width of the shadow path gives information about these, and this information is such that we have an explanation of at least one second more, and perhaps of two seconds. The path was narrower, indicating that the diameter of the moon used in the prediction was a little too small, or that of the sun a little too large, or perhaps both. Thus there are only two seconds at most to be attributed to the place of the moon in her path, and this means that at most the moon was one second of arc away from her predicted place.[1]

THE CORONA.

The corona is one of the most elusive phenomena which nature presents, since it has never been seen except at the time when the face of the sun is covered by the moon. The difficulty in observing it at any other time is caused by the glare of the sun lighting up our atmosphere to such an extent that anything near the sun which is not very bright is quite blotted out. Its brightest part gives out only about the same light as the full moon, and this is many thousands of times less than that of the sun.

The corona appears to the eye as bright streamers of light extending in all directions away from the surface of the sun. These streamers are of different lengths and are not the same from one eclipse to another. They can sometimes be traced as far as three diameters of the sun from its surface, fading out gradually as we look further away. We know little about their cause, whether they move, or of what they are composed. On all these questions information is sought at the time of an eclipse.

One thing has been learned in the past. When the sun is frequently exhibiting spots on its surface, the corona is nearly equally extended in all directions, so that its outline to the eye is circular. But at times when there are few spots the coronal streamers appear to extend mainly from three or four areas, so that it will have a quite irregular outline. The numbers of spots on the sun have been long observed and it is well known that there

[1] The final calculations showed that the sun was responsible for four seconds of time and the moon for one second. The errors of the diameters were quite small.

is a great outbreak of them about every eleven years, with periods in between when there are few or no spots. Thus the shape of the corona at any eclipse can be predicted to some extent. At the 1925 eclipse, it was foreseen that it would be nearly that which corresponded to a time of few spots and so it turned out.

Nevertheless, the record of the shape of the corona at each eclipse should be obtained for future study, more particularly since the time for obtaining it is so short. In earlier days before photography was a fully developed art, but little could be learned. Neither the professional astronomer nor the artist could give a picture which would serve for detailed study, in the few brief minutes during which it was visible. The early drawings are interesting if only to show what different impressions of its form could be obtained by those whose object was to make an accurate record of its size and shape. Photography has altered the situation completely. Pictures can be taken which may be developed and studied later. No one photograph is sufficient. A short exposure is necessary to show the details of the portions close to the surface of the sun, while a longer time is needed to bring out the fainter streamers further away from the surface.

So many possibilities of failing to get a record owing to cloudy skies were present that everyone who had a camera under a clear sky was asked to secure a photograph, and instructions were printed in the newspapers and elsewhere giving the times of exposure and other details. As a result, thousands of pictures of all kinds were taken, from the best to the worst. Even if the astronomers had failed to secure a single photograph with their special equipment, a complete record of the streamers could have been obtained from the work of the amateurs.

For the first time, moving picture operators made extensive preparations to secure films of the whole phenomenon. It is true that one or two attempts, one at least successful, had been made at the eclipse of September, 1923. In 1925, however, the news producers as well as a few private individuals had their cameras pointed at the sun for the whole time. At the Yale Observatory, three were attached to telescopes with driving clocks which automatically kept the lenses pointed directly at the sun all the time. Fortunately, the skies were clear, particularly at New Haven, Middletown, and Easthampton on Long Island, and some excellent

reels were obtained by the professional observers. Two films were also secured from the airship *Los Angeles*.

Very little is known about the constitution or nature of the corona, and the only way at present of obtaining information is by an analysis of the light which it gives out. While it is perhaps generally recognized that we can know nothing about any celestial object except by means of the light which it sends to us, it is not realized that the rays would fail to give us information unless we had some means of relating them to the physical properties of the bodies. These relations have first to be carefully investigated in the laboratory, the laws which are found there being then applied to bodies which we cannot bring within our grasp. The most important of all the methods is the analysis of light by means of the prism, or by its more modern equivalent, the diffraction grating. Until it became known that every substance when heated gives out light which is characteristic of that substance and which is never the same as the light given out by a different substance, not much progress could be made. The same substance in the form of a gas will blot out the same colors which it will give out when heated. It is known further that matter treated in different ways will give out light of different colors. An immense amount of work has been put on this subject by physicists. A large part of our knowledge of the nature of matter is derived from the investigation of the radiations which it sends out under different conditions.

Astronomy has not been slow in making use of this knowledge. The various devises used in the laboratory to examine the nature of the light given out by different substances are applied to the light received from celestial objects. Each instrument contributes its quota of information, and the assemblage of the results enables deductions to be made.

The fact that each substance gives out its own characteristic light first revealed the knowledge that a substance, not then known on the earth, existed in the sun. The non-committal name of helium was given to it. A painstaking search finally revealed it as existent on the earth and it is now used to fill our dirigibles. In the corona, there are certain colors—lines of light in the spectrum—which are not yet known to belong to any substance existing on the earth. The non-committal name of "coronium" has been given to this substance. It may be some known substance

which exists near the sun in a condition which we have not yet been able to reproduce in the laboratory, or it may be some element which has not yet been discovered on the earth. The way of approach to knowledge concerning it is to obtain all the information possible by examination of the light at the time of an eclipse, and then to search in the laboratory until the same results are obtained.

It will thus be seen why, at the observatories, various astronomers concentrated their attention on different phases of the corona. Some had instruments which should give photographs of particular parts of its color scheme or "spectrum" which, in the past, had not been sufficiently recorded, and some new "lines" were in fact obtained. Others were interested in measuring the intensity of the light at different distances from the sun's surface, and for this purpose the latest devices for measuring it were used. There were observations also of the intensity of the general skylight during totality in different parts of the sky. Nearly all the devices used were designed to give photographic records which could be studied at leisure at a later time.

It will thus be seen that the eclipse is, in the main, the time when the facts are learned and that it may be months or years before these facts can be properly interpreted. The opening up of a new region may produce startling discoveries, its exploration is usually a process of gradual addition to our knowledge and of still more gradual deduction of the laws which govern the actions of the physical universe.

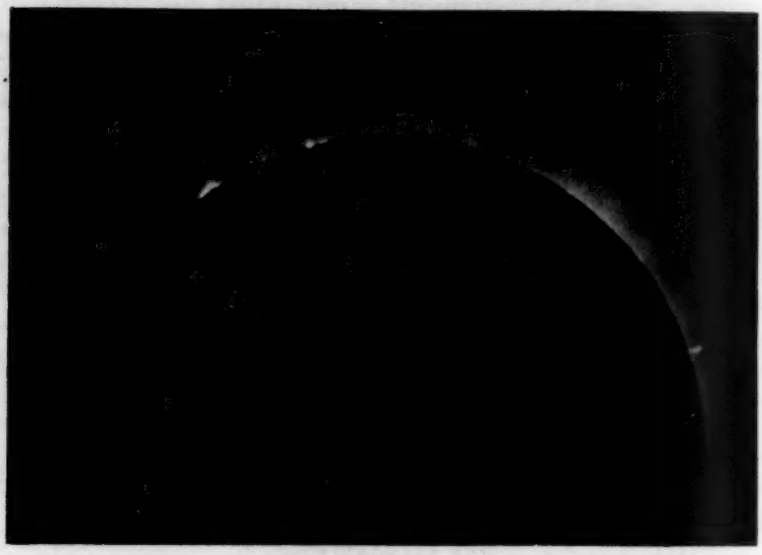
THE DIAMOND RING.

This was an effect which was particularly noticed and photographed in New York City. Its general appearance was that of a faint circle of light with an intensely brilliant place at one spot, the rays from which spread out and gave the impression of a ring with a big diamond inserted in the usual way. It was somewhat of a surprise to many because little or no mention of its occurrence had been made in the descriptive articles appearing before the eclipse. Its beauty was a compensation for the absence of the onrush of the shadow.

The explanation is not difficult. The corona can be seen on the darkened edge of the sun several seconds before totality occurs —it was actually photographed some sixteen seconds before—and

its faint light formed the ring. If the edge of the moon had been smooth there would still have been a crescent of the sun visible and totality would have occurred by this crescent getting thinner and then suddenly disappearing by the two horns coming together. There was, however, some depression in the moon's surface through which the rays of the sun were still visible after the crescent had closed up, and the intensely brilliant " diamond " was this last sight of the sun's surface shining through a lunar valley.

FIG. 3.



The prominences and inner corona. (Photo by C. L. Stearns at the Yale Observatory.)

It lasted somewhat longer in New York because the edge of the shadow crossed that city and the moon was therefore grazing the edge of the sun for a longer time. The same phenomenon was, of course, easily visible at all places along the northern and southern edges of the shadow.

THE PROMINENCES.

These flame-like appendages to the sun are always one of the characteristic sights of an eclipse. Their brilliant red coloring, the heights to which they rise above the surface, and the variety of the forms which they assume always add to the interest of the occasion. They are of less interest to the astronomer at this

time, because he has been able to photograph them without needing the moon to blot out the rest of the sun's surface. They seem to be masses of gas, largely hydrogen, shot out from the surface, with velocities which sometimes reach hundreds of miles per second, to heights of hundreds of thousands of miles above the surface. Several were visible at the time of the eclipse. One was in the form of an arch with its crown some forty thousand miles high and a base of double that extent. Another looked like a big splash, and still another appeared to have just emerged from the surface, its outline being sharp and heavy.

The prominences differ from the corona not only in color, but also in brightness. It is a fact well known to all photographers that the photographic plate is much less sensitive to red light than to blue. In spite of this fact, these structures are so bright that they not only impress their images very strongly on the photographs taken during totality, but these images "spread" on the negative, giving the appearance of a nick made in the edge of the moon. On large scale photographs this has to be distinguished from nicks which are caused by the irregularities of the edge of the moon.

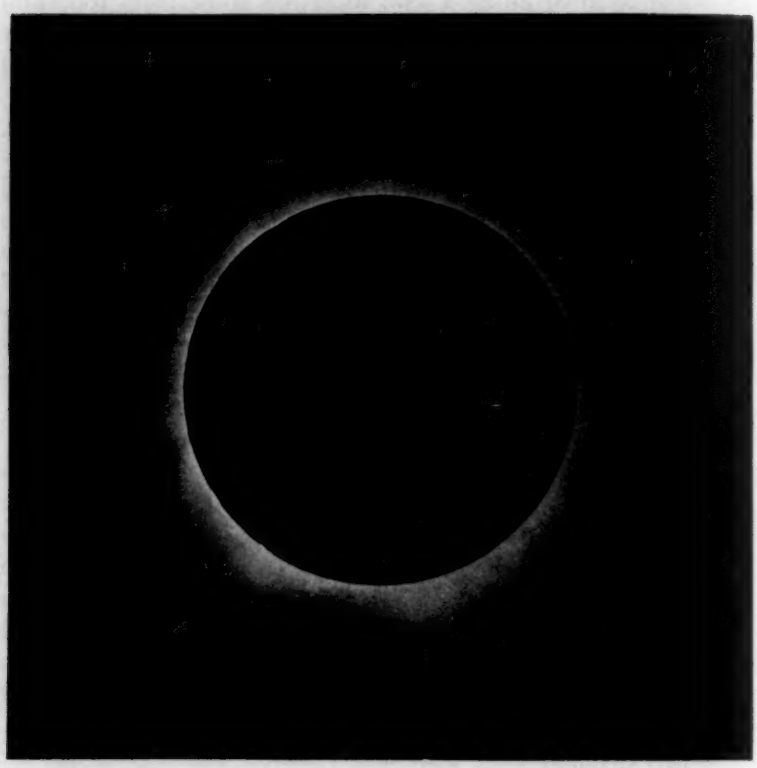
THE FLASH SPECTRUM.

When the sun's light is split up into a colored band by means of a prism, the band is seen to be crossed by thousands of black lines. These black lines are now known to mean that there are substances between us and the original source of the light which blot out or absorb the light at those particular places. As explained above, it is further known what substances cut off or absorb any particular part of the light, that is, those which produce the various black lines. We can therefore tell what materials constitute the outer envelope of the sun's surface. Below this envelope there is evidently matter which gives out the light. As the moon travels over the face of the sun at an eclipse, the light lessens, but the dark lines are still visible against the bright background. In the second before totality occurs, the whole appearance changes. The black lines suddenly become brighter than the background for a fraction of a second, and then change again, when totality occurs, to give the characteristic "spectrum" of the corona. It is this sudden brightening of the black lines which is called the "flash."

The photography of the flash spectrum, since it usually lasts

for less than a second of time, requires great alertness on the part of the observer. He is prepared for it by the predicted time of totality, but must watch for its actual occurrence through another telescope and make his exposure only during the time it lasts. Some unusually successful plates showing it were secured at the

FIG. 4.



The corona. (Photo by F. Slocum at the Van Vleck Observatory.)

eclipse and they seem to exhibit a number of bright lines which had not previously been recorded. The measurement of the exact positions of these will furnish more material for the physicist in the laboratory to be used for comparison. Prof. H. D. Curtis, of the Allegheny Observatory at Pittsburgh, who brought his spectroscope to New Haven, reports a whole new range of bright lines recorded on the two plates which he secured, one just before and one just after totality. Here was a quite definite result of the

1925 eclipse which became known within a couple of months after the event occurred.

A knowledge of the flash spectrum is valuable because it gives information concerning the matter of the sun below the envelope which we see at ordinary times. The better the photographs, the more we can learn concerning the materials which constitute this layer and the conditions under which they exist. Again this is a case of continued exploration of a region, previously partly known, which in the future may furnish more knowledge of the luminary on which we are so dependent, but for which we must wait until careful study has evolved the correct conclusions to be drawn from the observations.

THE EINSTEIN EFFECT.

The theory of this effect demands that the light of a star should be slightly bent when it passes near the edge of the sun, causing the star to be apparently slightly displaced away from the sun. It can be tested only at the time of an eclipse because stars sufficiently close to the sun can be photographed only at that time, owing to the glare caused by the sun when shining at its full strength. After such a photograph is secured, the same stars are again photographed when the sun has moved to another part of the sky. The careful measurements and comparisons of the distances between the stars on the two plates gives the amount of the displacement at the time of the eclipse.

The effect is so small that to measure it at all accurately, the conditions at the eclipse must be favorable. Stars bright enough to be well photographed during the brief time totality lasts must be present near the sun, and the atmospheric conditions must be such that their images on the photographic plate will be small and sharp. Neither of these favorable conditions existed at the time of this eclipse. The star field was poor, and as the sun was not very high in the sky but little confidence could be placed in measures which might be made on the plates. Thus no attempt was made to obtain any test of this nature.

The work done at two previous eclipses giving the predicted amount has removed most of the doubts as to the validity of the theory from the minds of the majority of astronomers. There are still, however, those who believe the effect may be due to refraction in the cone of shadow caused by the presence of the

moon, and it was hoped that a test of this might be made by photographing the moon with the corona as a background and by measuring the plate to find out whether the diameter was altered sufficiently to account for the effect in the manner suggested. It is doubtful again whether plates sufficiently good for this purpose have been secured. Such evidence as exists, gleaned from the observations of the duration of totality and the width of the shadow band, seem to negative this explanation.

THE SHADOW BANDS.

A complete programme for observation of this phenomenon was undertaken by members of the Faculty of Wesleyan University. This included not only observations in the usual way, but attempts to photograph them with a moving picture camera. The knowledge of the source of this picturesque appearance at the time of an eclipse has been increased to such an extent that it is doubtful if much work on them will be done by astronomers on future occasions.

It has long been supposed that the bands were due to motions of our atmosphere making irregular refraction in much the same way that a heated surface in summer makes objects appear to dance above it. The observations at Middletown showed that the bands were in some cases formed close to the ground and that they depended on swirls in the air caused by the wind. In one case they were observed chasing one another in all directions round a tree. In other cases they were quite poorly defined, just patches of light and shade, moving with all sorts of speeds and having different directions in different places. At various eclipses, they seem to have had more regularity, probably because the air currents were a little more regular. It had been hoped that something about our atmosphere might be learned from them, but the explanation for their occurrence gives little hope of this.

What has been written in this chapter by no means completes the story of the eclipse. The scientific side is necessarily given only in broadest outline, even so far as it is known at the present moment. The less technical descriptions also might be expanded to a considerable extent without exhausting the material available for the interested historian. It would be difficult to name any two minutes in the world's history for which so many preparations were made and about which so much has appeared on the printed

page. Whether it was worth the effort is a question which will naturally occur to the philosopher who is in the habit of contemplating the activities of humanity. The mathematician might reply by showing that the product of two minutes by ten millions of people gave an addition of forty years to the sum of human enjoyment and instruction! But the better answer is found in the thought that the people all together forgot their earthly concerns for a moment in order to receive a wider vision of the universe.

An Instrument for the Rapid Measurement of Low Pressures in Gases and Vapors. ERNST BRUECHE. (*Ann. der Phys.*, No. 8, 1926.)—A McLeod gauge can often be used to measure pressures ranging from .0005 to .02 mm. of mercury, but its use is impossible in two cases, *viz.*, vapors and, again, gases that attack mercury. There are two absolute manometers available for gases that combine with mercury as well as for those that do not combine. Of these Knudson's instrument requires a long time for a single measurement. The second was devised by Langmuir in 1913 and elaborated by Haber and Kerschbaum a year later. The main feature of this instrument was a thread of glass or quartz supported at one end in the space where the gas pressure is to be measured. When this thread is bent aside and released, it proceeds to vibrate with an amplitude that grows less with the passage of time. The lessening of the amplitude is due (*a*) to the internal friction of the thread itself, and (*b*) to the damping of the surrounding gas. The greater the gas pressure, the more quickly do the vibrations die away and the sooner does the thread come to rest. Langmuir selected quartz because its internal friction would count for less than the damping of the gas. Under the guidance of theory a thread 90 mm. long and .2 mm. in diameter was employed by the German investigators. With such an instrument the lengths of time required for the amplitude to die down to one-half of its original length were as follows:

Pressures in mm.	Gas. Hydrogen.	Oxygen.
.00001	740 sec.	735 sec.
.0001	710	620
.001	510	360
.01	160	40

The apparatus has several advantages, such as applicability to both gases and vapors, simplicity of construction and small size. It is, unfortunately, subject to serious disadvantages. As the table above shows, its action depends upon the molecular weight of the gas.

It lacks sensitiveness at low pressures, needs from 3 to 20 minutes for a single determination, is very susceptible to shock and the thread may easily be made to describe a Lissajous figure instead of the desired straight line.

The author has succeeded in the construction of a manometer superior to the thread manometer discussed above. A leaf of quartz, 25 mm. square and .04 mm. thick, is suspended from a support by two quartz bands 75 mm. long and .8 × .1 mm. in cross-sectional dimensions. The apparatus is mounted in a glass tube 4 cm. in diameter in such a way that the leaf lies in a vertical plane. An electromagnet is placed outside the tube but sufficiently near to attract a piece of soft iron attached to the lower part of the leaf. Thus the latter is made to swing to and fro without twist. A sharp point on the wire is projected on a screen for facilitating observations of damping. This screen is ingeniously made of rubber arranged to be stretched so that the image of the point may easily be made to coincide with a division mark on the scale. The time of a complete vibration of the system is .45 second. The range of possibilities of such an arrangement is shown by the fact that two systems of different dimensions took, respectively, an hour and a minute for reduction of the amplitude of vibration to half of its initial value, the gas pressure being the same in both cases.

The particular manometer of the new type was especially suited to measurements of pressures between .0005 and .02 mm. for which only a minute was needed. Other instruments could be made for any selected range of pressure from .00001 to .5 mm. The new instrument has the valuable property of increasing in sensitiveness as the pressure diminishes.

Strange to say, this instrument designed for refined measurements of low pressures lends itself to demonstration experiments before an audience. For example, by its use can be displayed the rapid reduction of the vapor pressure of fatty material used at the joints of vacuum apparatus when condensation by liquid air is produced.

The mathematical formula for the functioning of the manometer, besides three constants dependent on the instrument, contains two constants characteristic of the gas under measurement, the molecular weight and the coefficient of viscosity. While it is improbable that molecular weight will ever be accurately found by this method, yet for the identification of a gas it has its use. For example, a vacuum apparatus containing air was thoroughly pumped out and allowed to stand for twenty hours. At the end of that time some gas had collected. The pressure was determined by a McLeod gauge and the product of pressure and molecular weight was furnished by an observation taken on the manometer. By combining the results the author found the molecular weight of the trace of gas to be 30, thus showing it to be air. G. F. S.

ENGINEERING REMINISCENCES.*

BY

SAMUEL REA, Sc.D., LL.D.

Retired President, Pennsylvania Railroad; Franklin Medalist, Honorary Member of the Institute.

THE award of the Franklin Medal, by this distinguished society, is a very great honor, one of the highest which may be conferred upon a member of my profession. Coming to me at the close of a long and active career in engineering and railroad management, I assure you it is deeply appreciated, particularly as a mark of recognition from so eminent an institution of this city, in which the greater part of my life work has been carried on.

It seems to belong chiefly to elderly men to recount the past and deal with reminiscences. For my part, however, this is not the case, as I have not merely acquired the habit in my mature years or since my retirement from active duty. There is a saying that to have knowledge of what occurred at a distant period is the same as though one had lived at that time. Impressed with this truth, I have always tried to profit by it through reading history and biography, and familiarizing myself with the occurrences of the past and with the outstanding figures and exemplars of history.

Starting on an engineer corps of the Pennsylvania Railroad in 1871, only seventeen years after the road had been put in operation between Harrisburg and Pittsburgh, it was my good fortune to come in personal contact with many of the older engineers of the company—especially those who had been on the location and construction of the Main Line of the Pennsylvania and its early branches. Through them I also had the advantage of meeting other important railroad engineers of the country, who had first worked on surveys and location of canals and later on railroads. In that manner I gained a variety of viewpoints, and in addition absorbed from their experience a vast amount of knowledge on engineering, which would have been most difficult to gain in any other way.

Among those earlier engineers of the Pennsylvania, whose names are still familiar to Philadelphians, were George B. Roberts,

*Presented at the Stated Meeting held Wednesday, May 12, 1926.

Strickland Kneass, J. N. DuBarry, Oliver W. Barnes, James R. McClure, William H. Barnes and George W. Leuffer. All of them were active working engineers on the location and construction of the Main Line of the Pennsylvania Railroad, under John Edgar Thomson, Chief Engineer. John Edgar Thomson was a commanding figure in the engineering profession of his time. He was born in Delaware County, Penna., in 1808, and as early as 1832 was Chief Engineer of the Georgia Railroad, from Augusta to Atlanta, with branches, on which he remained until 1847 when he was appointed Chief Engineer of the Pennsylvania Railroad. He was elected President of the Pennsylvania in 1852 and continued in office until his death in 1874. Although I was on the Pennsylvania during Mr. Thomson's presidency, I never met him. All the others mentioned I knew intimately.

Another prominent engineer, who was a contemporary of John Edgar Thomson, and worked with him on the early surveys for the Philadelphia and Columbia Railroad, and who afterward also rose to distinction in the profession, was William Hasell Wilson, who was born in Charleston, S. C., in 1811, and died in Philadelphia in 1902.

It was my privilege to know Mr. Wilson very well during the last twenty years of his life. He was a quiet, modest, retiring man, but well trained in his profession and with a great fund of knowledge concerning it. He enjoyed exceptional advantages by reason of vast practical experience in surveys, construction and maintenance of way work on the Pennsylvania Railroad and was especially active as Chief Engineer, during the Civil War, when he was located at Altoona. On August 2, 1892, the achievements of Mr. Wilson's career received signal recognition from his profession through the award of Honorary Membership in the American Society of Civil Engineers. It is an interesting fact that in 1839, or fifty-three years before this event, Mr. Wilson participated in the initial movement looking to the founding of an engineering society. A meeting of civil engineers, which he attended, was held in Baltimore for that purpose, but in those days members of the profession were few in number and were widely scattered, so that the effort was temporarily dropped for lack of sufficient support. In 1852, however, the movement was resumed and the American Society of Civil Engineers was actually organized. It seems fitting, indeed, that one of the distinguished

pioneers in this movement should later receive the highest honors in the Society's gift.

The Wilson family was remarkable in the fact that William Hasell Wilson's great-grandfather, grandfather, and father were all engineers, and with himself and his three sons, made five successive generations in the profession. I may add that John A. Wilson, the oldest son of William Hasell Wilson, was the first Chief Engineer under whom I served when I first went to work for the company in 1871. He was then Chief Engineer of Construction.

When John Edgar Thomson was made Chief Engineer of the Pennsylvania Railroad in 1847, Mr. Wilson was unable to accept an appointment on his staff as he had other engagements, but later on became associated with Mr. Thomson, ultimately succeeded to the latter's post, and was otherwise connected with the company until the time of his death.

It was a great personal pleasure to me to know and converse with Mr. Wilson because he had a very accurate recollection of the early days of engineering, both on surveys for canals and for railroads, during the first half-century of railroads. In addition to his work for the Pennsylvania, Mr. Wilson also served on the construction of the Philadelphia and Reading under Moncure Robinson, to whom I will refer further.

He left a record of his reminiscences as an engineer, and it is pleasing to note that he records the fact that he received his technical education in part under the auspices of The Franklin Institute.

As I look back, I now perceive that these contacts with old experienced engineers were of inestimable value to me, a young man, who without technical education had to learn by study and experience under the tutelage of older engineers who had travelled the same road as myself. Here and there among them was only an occasional member of the profession so fortunate as to have secured collegiate and technical training. Many other engineers of the past who participated in the construction and development of our railroads could be cited, but there was one of outstanding character to whom I wish to refer because of his great ability, his professional achievements and particularly his early advocacy of railroads as against turnpikes and canals.

Thirty-five or forty years ago one could frequently see walk-

ing about the financial district of Philadelphia an elderly and venerable gentleman, with white hair, who had long been a resident of the city, and though out of active engineering work for many years was identified with various financial interests. His name, probably familiar to many of you, was Moncure Robinson. He was born in Richmond, Va., in 1802. He entered William and Mary College at thirteen years of age, and at sixteen had passed all his examinations for the degree of M.A., and after a well-filled life of notable activities, died in Philadelphia, November 10, 1891, in his ninetieth year.

I saw Mr. Robinson frequently, and also knew of him through other engineers. I regard his record as an engineer as being extraordinary. While still in his 'teens, and after he had completed a short section of the Virginia State Canal above Richmond, he was offered by the Governor a commission to undertake the construction of an extension of the canal system to Covington, about 250 miles distant. It is noteworthy, however, that instead of accepting, he urged the abandonment of the canal scheme in its entirety and the substitution of a railroad. Thus in that early period, 1821, he foresaw the great advantage of railroads over canals, and had the courage to advocate them, but unfortunately he was far in advance of the times, and the advocates of canals being in the majority, they went headlong into canal construction. Failing to win over the Virginia State authorities to his views as to railroads, on which he had taken a decided stand, he declined to participate professionally in the western extension of the James River Canal, as being incompatible with his ideas of the ethical requirements of his calling. Later his sojourn in France, Holland and England, his study of the engineering works of those countries, and his contact with their engineers, especially with George Stephenson in England, fully confirmed his own judgment as to the superiority of railroads over canals.

One wonders what would have been the history of railroads in this country if the advanced views of that young engineer, formulated one hundred and five years ago, had been generally adopted and the construction of railroads rapidly expedited. Instead, unfortunately, it was necessary for the country to await the experiments of the canal building period, to suffer the disadvantages of their operation for only a part of each year, and to see many of them operated to obsolescence within a compara-

tively brief interval following the vast expenditures made upon them, much of which was subsequently a total loss.

Mr. Robinson was consulted by the Canal Commissioners of Pennsylvania on plans for the Allegheny Portage Railroad, by which canal boats were to be portaged over the Allegheny Mountains between the eastern and western divisions of the canal. To these commissioners, who were laymen, was delegated the authority of the state to construct the Main Line of Public Works between Philadelphia and Pittsburgh and as a part of that duty to examine and report on plans for connecting the canal basin at Hollidaysburg with the basin at Johnstown. After many surveys and reports from different engineers, a railroad with inclined planes surmounting the Allegheny Mountain range was preferred, though consideration was likewise given to the feasibility of a route and water supply to carry the canal all the way through. A highway was also proposed by some engineers alongside the inclined plane railroad, but was not accepted. Mr. Robinson, while concurring in the plan for an inclined plane railroad, recommended a tunnel at the summit of Blair's Gap, which would have reduced the summit level about 140 feet and made possible the use of fewer inclined planes, but his advice was not taken and the Portage Road went over instead of under the summit.

No tunnels had been built in America up to that time, so the Canal Commissioners may be excused for their ignorance in not knowing what tunnels were. In reply to the inquiry, "What is a tunnel?," the apposite answer, from one of their engineers, was, "A tunnel is a large well dug horizontally through a hill or mountain, where there is not water enough to lock over it or where lockage would be too expensive."

A summit tunnel having been abandoned, the only tunnel on the Allegheny Portage Railroad, and the first to be built in America, completed in 1833, was through the spur at "Staple Bend" on the Conemaugh, four miles east of Johnstown. The tunnel is there to-day, although its use was abandoned about seventy years ago.

Mr. Robinson, as Chief Engineer, later located and constructed the Main Line of the Philadelphia and Reading Railroad. The portion between the cities of Philadelphia and Reading was completed in 1837. The location of the Reading Railroad, including

the Richmond Branch, with balanced gradients to best accommodate the loaded and empty traffic, is still regarded by engineers as one of the best in the country. It compares favorably, to-day, with modern locations, and has required less rectification than most of our early railroad locations. Mr. Robinson's selection of the Richmond Terminal property on the Delaware River, and success in inducing the directors to acquire it and connect it with the Main Line, showed great foresight as to the future of that valuable freight terminal for the Reading System.

While regarded as a civil engineer, Mr. Robinson, like many other engineers of his time, did not confine himself solely to that branch of the profession, because he was broadly interested in all features of a railroad. Therefore, we find him designing and having built by Eastwick and Harrison, of Philadelphia, a locomotive for the Philadelphia and Reading Railroad as early as 1838. It was named the "Gowan and Marx" in honor of friendly bankers in London. Not many engineers of the present time, with the profession so specialized in many branches, have similar opportunity of working outside of the branch in which they have been particularly trained.

In 1890, as Chief Engineer of the Baltimore Belt Railroad (part of the Main Line of the Baltimore and Ohio Railroad, through and under the City of Baltimore), I had the great pleasure of conversing with a man who had been present at the laying of the first stone in the construction of the Baltimore and Ohio Railroad. That man was John H. B. Latrobe, who was born May 4, 1803, and who died September 11, 1891. It was a great honor that he should ask to see me in order to have explained to him our work of tunnelling under Baltimore. Mr. Latrobe entered West Point in 1818, at the age of fifteen, but resigned, when he stood at the head of his class, in 1821, on account of the death of his father. His West Point training probably gave the impression often repeated that he was an active engineer before he became a lawyer. I certainly had that impression in talking with him, noting his broad knowledge of railroads, and believed that he had told me so, but on searching the record I find I was mistaken.

Mr. Latrobe's long connection with the Baltimore and Ohio Railroad, as counsel for more than sixty years, and his association with its engineers, made him very conversant with engineer-

ing matters as I found from his searching questions about the Belt Line. I recall his keen interest in my descriptions of the Belt Line, its tunnels and other structures, which, however, could not compare with my own interest in his career, and the thought, which was ever present, that I was conversing with one who participated in the very beginning of railroads in the United States. My own career has covered the second half of the first century of railroads, and my conversation with Mr. Latrobe familiarized me, at first-hand, with one who had lived and worked and legally guided his company through the first half of that century as counsel for the oldest trunk line.

Benjamin H. Latrobe, a younger brother of John H. B. Latrobe, born in Baltimore in 1806 and died in 1878, was for many years eminent in the profession and Chief Engineer of the Baltimore and Ohio Railroad and had much to do with the extension of the Main Line through to Wheeling. He was also President of the Pittsburgh and Connellsville Railroad. He started his career as a lawyer but subsequently gave that up and became an engineer. His professional friends on the Pennsylvania Railroad, while building the western section of that road, laid out a town on the banks of the Loyal Hanna River, in Westmoreland County, Penna., and in his honor called it Latrobe.

The Latrobe family has been well represented in the engineering profession. One of the descendants, Gamble Latrobe, was an engineer on the Pennsylvania, and at the time of his death in 1922 was General Superintendent of the Southern Division of the Pennsylvania Railroad. He was the son of Charles Latrobe, also an engineer, and a grandson of Benjamin H. Latrobe.

Among other reminiscences of my engineering career which I recall, was my experience as a young engineer on the "Point Bridge" at Pittsburgh in the course of its construction during 1875 and the Centennial year, 1876. This unique stiffened chain suspension bridge, designed by that talented German engineer, Edward Hemberle, was built by the American Bridge Company, of Chicago, and caused widespread interest among engineers, especially those from abroad, many of whom were visiting the country on account of the Centennial Exhibition, and all of whom wanted to see the bridge. Mr. Hemberle certainly proved that he had the courage of his convictions by using wrought-iron eye-bars in the chains and attaching the stiffening directly to the chain instead

of adopting the usual heavy stiffening trusses along and at the roadway level. These eye-bars were fabricated by welding the forged heads to the bars. The traffic having outgrown the capacity of the bridge, it is now being replaced, though still in good structural condition after half a century of use.

Hundreds of engineers from many different countries visited the "Point Bridge" on their travels around the country after seeing the Centennial Exhibition, and part of my duties was to show them the work. One visitor whom I happen to recall quite vividly—perhaps from his intense interest in the work—was Paul Panieff, a Russian professor of engineering, who went over the detail plans and the work of erection of the bridge with the greatest care and interest. Similarly, no doubt, hundreds of engineers visiting Philadelphia in this Sesqui-Centennial year will be deeply interested in the opening for traffic of the Delaware River Bridge, for we may be sure that every engineer coming here will want to see and learn all about it.

It was, if I remember correctly, some two or three years after the completion of the "Point Bridge," while I was still in Pittsburgh but had reëntered the Pennsylvania Railroad service, that I first made the acquaintance of that eminent civil engineer, Gustav Lindenthal, who was then rebuilding the Smithfield Street Suspension Bridge, in that city. Out of that meeting grew a personal friendship and professional association which have lasted to the present day, and were particularly close and intimate during the period when we were planning and carrying out our New York Tunnel and Terminal project.

Unquestionably the officers of the Pennsylvania Railroad of fifty and more years ago, most of whom were or had been active civil engineers, clearly realized that the road was the nucleus of a great railroad system of national importance, which, for its ultimate development, logically required a terminal of its own, reached by its own rails, in the heart of the country's metropolis.

We may be sure that this feeling became particularly confident after the extension of the system, by lease, to Jersey City, and that our officers of that day must have perceived clearly that reaching Manhattan by ferry could only be regarded as a temporary measure to be used until direct entrance could be effected.

We know definitely that as early as 1874, when the first actual attempt at tunnelling the Hudson River was made, though

unsuccessfully, our management was keenly interested; and this interest never subsided, though our officers did not at that time, or subsequently, approve the use of steam locomotives in subaqueous tunnels, and electric traction had not yet been developed. How the thought was nourished and fostered, and how at length the advance in electrical engineering, with the resulting ability to use electric power for heavy railroad traffic, made our tunnel extension practicable, have been recorded elsewhere. I will, therefore, not attempt more than a glance at the subject now.

It is interesting to recall, however, that at first the most feasible method for effecting a direct entrance into New York City seemed to be by means of a high-level bridge. This was partly, though not entirely, on account of the objection to the use of steam locomotives in tunnels, to which I have just referred. In 1884, Mr. Lindenthal prepared a plan of such a bridge for the Pennsylvania Railroad. This appealed strongly to our officers and directors and studies were made, but no further action taken. But the matter was not dropped by Mr. Lindenthal and others associated with him. They continued their efforts and, later, definite plans were worked out for a bridge to be used as a post road, open to all railroads. As a result, a Federal charter was granted to the North River Bridge Company in 1890, after careful and exhaustive hearings. The report of the Committee on Commerce of the House of Representatives, on this subject, is an important document of that period. It recited the necessity for the bridge, expressed the opinion that it should be a national work and built under national authorization, pointed out that the project was not only of commercial importance to the immediate neighborhood of New York City but to the whole country, and showed that such a bridge would be a gateway for the commerce of all the surrounding states into and out of the commercial metropolis.

The project was not realized, however, owing in part to the fact that the other railroads would not, or on account of their financial condition could not, participate in financing the bridge. The Pennsylvania, while deeply interested in the bridge, could not properly risk its credit for the benefit of all railroads, and so was obliged to proceed with plans for going ahead alone. This resulted in the final adoption of its tunnel system.

In passing I may say that while the day for the construction

of such a bridge in lower New York City, over the Hudson, primarily for steam railroad traffic, may have gone, the immense growth of passenger and highway traffic across the Hudson River, which has occurred since the development of the automobile and the Hudson and Manhattan Railroad, with the continued rapid development of the Newark territory, keeps the project fully alive. I for one believe that the cost of such a bridge for highway, suburban and local traction use would be fully justified; that its revenues would carry its capital investment, and would ultimately amortize the cost and give a free bridge to the public.

New York, the chief beneficiary of such an important transport artery, so located as best to serve the bulk of the traffic, has not yet awakened to its necessity and may not until intolerable congestion will compel its construction. When that time comes, it will be found that the wisdom of Congress was fully justified in creating the North River Bridge Company with its broad powers, but still safeguarding the public in every way, with profits limited to 10 per cent. of its cost, and all under the supervision of the Interstate Commerce Commission, and all declared constitutional by the Supreme Court of the United States It will also be apparent that the existing charter will continue to be the most appropriate and best instrumentality for carrying out such a great interstate project.

While we have not yet seen the realization of these plans for a bridge connecting Manhattan Island with the Continent, notwithstanding the necessities for one recited by the Congressional Committee thirty-five years ago and since greatly intensified. Mr. Lindenthal has left us, in the Hell Gate Bridge, of which he was Chief Engineer and Architect, an imposing and extraordinary example of the bridge-builder's art. An essential feature of our New York Extension project, the Hell Gate Bridge, with its thousand-foot steel arch, is one of the most majestic and remarkable structures in the world. The work of designing and constructing it, alone, would justly entitle Mr. Lindenthal to a place in the first rank of the engineering profession, even without considering the many other notable achievements of his career.

Construction work on the Pennsylvania Railroad's Hudson River tunnels was begun in 1903 and on the Pennsylvania Station in 1904. The station was opened for traffic in 1910, while the Hell Gate Bridge, which linked our system with the New England

lines by a direct all-rail connection, thus bringing the entire project to its logical completion, was opened in 1917. The period of construction work, of course, was preceded by years of thought and planning, dating back in my own case to 1884 and to my studies of the London Underground Tubes, made in 1887 and 1892. From 1899 to December 31, 1912, as a Vice-president of the Pennsylvania Railroad, in addition to my regular duties, there was delegated to me the responsibility, under the President, of organizing for the work of construction, supervising its conduct, acquiring the property necessary, and directing all corporate work incidental to the project. This was, of course, the most important engineering work of my career and required the closest and most unremitting attention during the entire period.

I have felt that on this occasion it was appropriate, indeed a duty, to give some facts and incidents, accumulated during my career, concerning the engineering profession, as a partial record of the last fifty years of railroads. Much more could be related and many more engineers cited, especially those who located our western railroads. Reference could also be made to my pleasant engineering acquaintances in England, and to the many engineering projects with which I have been connected or helped to promote, but I trust that what I have recited may be of interest to the members of The Franklin Institute to whom I am deeply indebted for the honor this day conferred on me.

Research Fellows at Carnegie Institute.—Thirteen graduates of colleges and universities have been appointed Research Fellows to conduct an unusually extensive program of studies in mining and metallurgy at the Carnegie Institute of Technology during the coming year, according to a recent announcement. The work, as in the past, will be carried on by the Department of Mining and Metallurgical Engineering, in coöperation with the Pittsburgh Station of the U. S. Bureau of Mines and under the direction of two advisory boards of engineers and business men representing the mining and metallurgical industries.

Of the thirteen investigators, five will study problems in metallurgy and eight have been assigned to carry on research in problems relating to coal-mine engineering. The program of metallurgical studies will be supervised officially by an advisory board of Pittsburgh District steel men and engineers. The coal-mining investigations will be made under similar conditions with an advisory board of coal operators and mining engineers.

Four of the studies, it is announced, will be financed by the

Carnegie Institute of Technology, while the remainder of the work will be underwritten by the industries.

Senior investigators to assist the Research Fellows will be furnished by the Bureau of Mines. The following are some of the problems which have been selected and assigned for the coming year: "Constitution of Low-temperature Tar," "Coal Ash Fusibility as Related to Clinkering," "Solubility of Iron Oxide in Iron and Its Effect on Physical Properties of Pure Iron," "Flammation of Fine Sizes of Coal Dust," "Electric Power of Storage Batteries *vs.* Trolley Locomotives," "Warning Agents for Manufactured Gas," "Mine Timber Treatment," "Case Carburizing of Steel." R.

Philadelphia Sesqui-centennial, World's Greatest Light Spectacle.—Illumination has been of course always an important feature of all expositions, but at the Sesqui-centennial more lavish use has been made of lighting to carry out the desired effects than at any previous affair of this kind. The outstanding lighting feature of the Sesqui-centennial is the luminous Liberty Bell at the Plaza, designed by D. W. Atwater, of the Westinghouse Lamp Company. Towering eighty feet above the sidewalk, the tremendous replica of the historic bell contains over 26,000 fifteen-watt lamps in amber, ivory and rose colorings. The structure contains eighty tons of steel, and rests on a foundation thirty feet deep, built of wooden piling and concrete capping. The columns on which the support of the bell rests are made of plaster and painted a bronze metallic color to blend with the predominating golden-amber hue of the luminous bell.

The Tower of Light, stretching far above the other exposition buildings, when illuminated at night, is visible from all parts of the city as a lofty silver shaft shedding brilliant light. The tower, which is 200 feet high, is located between the two main exposition buildings, right in the centre of the exposition. A sixty-two-inch Sperry searchlight, the largest ever built, is mounted on top of the tower, and is used to sweep the exposition grounds and prominent buildings in Philadelphia.

Twenty-four immense searchlights with a combined intensity of 10,800,000,000 candle-power are located at the exposition grounds, and will form the greatest concentration of light ever seen in one spot in the history of the world. These searchlights are placed at intervals along both sides of the exposition grounds, and are equipped with color screens to form fantastic light effects. One of the many unique searchlight effects will be an immense colored aurora.

Ornamental standards and floodlights illuminate the Grand Court and produce an effect never before attempted. The towers of the exhibition palaces are brought out in a pleasing blaze of color and contrast. The Gladway, which adjoins the Grand Court on the west, is illuminated by myriads of light of various magnitudes. The lagoons are swept by vari-colored floods of light. R.

THE CONTRAST OF PHOTOGRAPHIC PRINTING PAPER.*

BY

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SECTION A. INTRODUCTION.

I. GENERAL STATEMENT OF THE PROBLEM.

PHOTOGRAPHIC papers are classified very largely, both by the manufacturer and by those who use them, with respect to that quality which is designated as " contrast." The trade names by which these materials are known almost invariably contain some verbal specification of the contrast characteristic. Among the terms used as indicative of this may be mentioned *hard, soft, normal, contrasty, vigorous, etc.* For the purposes of classification and as an indication of adaptability to various purposes, a knowledge of the *contrast* of a printing paper is probably of greater importance than that of any other of its characteristics. While *speed* may be of prime importance in the case of negative materials, *contrast* is of far greater interest in the case of papers.

The meaning of the term *contrast* as applied to printing papers, while understood in a general way by the user and manufacturer of such materials, is somewhat difficult to define precisely. The verbal specifications employed at the present time are obviously indefinite and lacking in preciseness of meaning. In fact, the same word when applied to different brands of paper may indicate widely different contrast characteristics. The use of such terms for the specification of this very important characteristic is obviously inadequate, and it seems highly desirable, if possible, to find some method whereby *contrast* can be measured precisely and specified in numerical terms.

During the past few years articles have appeared, from time to time, in various photographic periodicals, dealing with this subject. The possibility and the desirability of finding a method whereby a numerical expression of this characteristic can be obtained has been discussed and several proposals have been made

* Communicated by Dr. C. E. K. Mees, Director of Laboratory, and published as Communication No. 264 from the Research Laboratory of the Eastman Kodak Company.

for obtaining a satisfactory solution. The majority of these involve the combination of two or more of the characteristic constants, determined by sensitometric methods, in such a way as to result in a single number which will be more or less precisely indicative of that characteristic of a printing paper referred to as its *contrast*.

In this laboratory this subject has been given considerable attention, and during the past four or five years extensive experimental work has been done in an effort to develop a logical and satisfactory solution. The problem is a very complicated one involving the consideration of many factors and while much further work needs to be done, this seems to be an opportune time to present the results thus far obtained.

Many interesting relations between the quality of negatives and the sensitometric characteristics of the printing paper producing the most satisfactory print therefrom have been found, and in the following pages a rather detailed account of the experimental work will be given, as well as some proposals as to a method for obtaining a series of numerical values which will truthfully represent the relative contrast of papers differing widely in sensitometric characteristics.

II. HISTORICAL.

The possibility of using various sensitometric constants of a printing paper for obtaining an expression of contrast has been considered by many workers in the photographic field, and several proposals for their utilization have been made.

Several years ago a communication from this laboratory [1] was published, dealing with the application of sensitometric methods to the determination of the characteristics of photographic papers which, so far as the author is aware, was the first attempt to apply to these materials the sensitometric methods originated by Hurter and Driffield. The blackness of the silver deposit was defined in a manner entirely analogous to the density values commonly used when dealing with light-transmitting materials, the logarithm of the reciprocal of the diffuse reflection factor being defined as reflection density. This method of defining reflection density is in agreement with that proposed by Renwick [18] and used by him in a study of the relation between the density values of silver deposits when measured by reflected

and transmitted light. In his work, densities produced in the usual way on transparent supports (glass or film) were placed in contact with a sheet of ground pot opal glass, optical contact being insured by the introduction of a film of cedar-wood oil, and the reflection factors measured relative to that of the opal glass.

Previous workers along similar lines had attempted to specify the characteristics of these deposits by rendering the paper base translucent by treatment with various materials, and then measuring the density by transmission. Since prints on paper and other opaque supports are intended to be viewed by reflected light, it is evident that their sensitometric characteristics must be determined on a basis of reflection factors or reflection densities if the results are to be of practical use in *tone reproduction* and *contrast* problems.

The question of contrast was discussed briefly in the publication mentioned. It was our opinion at that time that the gradient (γ) of the straight line portion of the sensitometric curve was the major factor in the determination of contrast and that the values of scale, maximum density, and rendering power were of secondary importance. However, no attempt was made at that time to combine the various sensitometric constants so as to obtain a single value for the specification of contrast. It was, however, pointed out that contrast is essentially a function of the differential of density with respect to exposure, $\frac{dD}{d \log E}$; and the use of the first derivative $\left(\frac{dD}{d \log E} = f(\log E)\right)$ of the usual H. and D. curve was proposed as a method for more graphically showing the contrast characteristics of photographic materials. While the first derivative actually contains no more information than the characteristic curve itself, experience has shown that this form of plotting the data is very useful and exhibits more strikingly some of the relationships existing between the various factors. Further study of the contrast problem since the publication of the paper mentioned and the accumulation of a large mass of data bearing on the subject has resulted in marked changes in our conclusions and, as will be shown later, we are forced to the conclusion that the value of gamma is of secondary importance in the determination of contrast and that the value of the mean gradient and available density scale are the predominant

determining factors. Since the publication of the paper mentioned, many other workers have adopted the same method for measuring and expressing the characteristics of photographic papers and there seems to be little doubt that it is very satisfactory for the purpose.

Formstecher [2, 3] has treated the subject of contrast especially from the standpoint of exposure latitude and of the relations existing between the characteristics of the negative and printing paper. While he did not make any definite proposal for the specification of contrast, his treatment of the subject is of general interest. Kieser,[4] after describing the well-known Hurter and Driffield method of expressing the characteristics of photographic materials (which he erroneously attributes to Eder), proposed that the slope of the straight line portion be taken as a measure of contrast or gradation. He suggests that the angle which the straight line portion makes with the log *E*-axis, expressed in degrees, be used as a numerical specification. Even if the slope of the straight line were an adequate expression of contrast, the expression of the value in degrees is fundamentally incorrect since such a procedure would produce a scale on which the values are not proportional to the subjective impressions produced. Hall [5, 6] proposed that the value of total scale be used as a means of expressing contrast and Taylor [7] also proposed the use of total scale, but in the reciprocal form and multiplied by a constant in order to obtain a series of whole numbers. As will be brought out later in the paper, the use of this value alone is hopelessly inadequate. Glover [8, 9, 10, 11] has treated the subject very carefully from the sensitometric standpoint and emphasized the fact that exposure scale alone is quite inadequate as an expression of contrast. He concludes that values of *gamma infinity, total scale, maximum density,* and *rendering power* are necessary for a complete specification of contrast. Of these he believes *gamma infinity* to be of greatest importance and *total scale* of almost as great value. His final conclusion is that it is rather hopeless to attempt any expression of contrast in the form of a single numerical value. As an alternative plan he proposes the use of a multiple test-negative consisting of six negatives, varying in contrast, from which test prints can be made on the various printing papers and a scale of six contrast steps thus established.

From this brief review of the literature it will be seen that

very little real progress has been made in reaching a satisfactory method of expressing contrast. The formulæ proposed have been based largely on reasoning as to what should be the influence of the various sensitometric constants upon the contrast of a printing paper and practically no data have been submitted to prove that the methods suggested do actually give numbers which are proportional to the effective contrast. While it is justifiable to reason that variations in the magnitude of certain of these characteristics must have a certain qualitative influence upon contrast, there seems to be no fundamentally sound method of deciding just how great an effect upon contrast will be produced by any definite variation in the sensitometric constants.

It seems desirable, therefore, to approach this problem from a somewhat different angle. If it is possible in any way to obtain for a given group of printing papers a series of numbers which are definitely known to be proportional to their contrast values, it may be possible to develop a formula whereby the constants determined sensitometrically can be utilized directly for the computation of a *contrast* value.

III. THE NATURE OF CONTRAST.

Fundamental Concept and Psychophysical Laws.—In the literature of photography, the word *contrast* has been used more or less loosely and several different meanings have been attached thereto. For the sake of clarifying thought on the subject and to aid in deciding upon a rational definition, it will be well to consider briefly the fundamental nature of the *contrast* concept. The dictionary gives the following definition as denoting general usage: "The opposition between things similar in some respects which are yet strikingly different." Obviously, this is a qualitative definition and has no quantitative significance, but nevertheless must form the foundation upon which the technical usage of the word has developed.

Contrast effectively, then, expresses a state of difference or unlikeness, but for our purpose we also need to know how such a difference must be expressed in order that a quantitative evaluation of the resulting contrast may be obtained. The most usual way of expressing the extent of the difference between two magnitudes is to subtract the smaller from the greater, this being termed the "arithmetical difference." A little consideration

shows, however, that this does not properly express the extent of the *contrast* resulting from such differences in magnitude.

This conclusion can be forcibly illustrated by a numerical example. Suppose two towers are standing side by side, one of which is 20 and the other 40 feet high. There is a marked *contrast* between the two as regards height; the arithmetical difference in height is (40–20) or 20 feet. Now consider a second pair, one 200 and the other 220 feet high. The arithmetical difference in height is (220–200) or, as before, 20 feet; but the magnitude of the contrast between the heights of the two towers in the second case is not so great as in the first case. It is evident that the arithmetical difference does not properly express our concept of contrast. If, however, the ratio of the heights be taken, a value of $40/20 = 2$ is obtained in the first case, and in the second $220/200 = 1.1$. These numbers indicate a greater contrast between the heights of the first pair than between those of the second and are more in accord with our ideas of the contrast in the two cases. It seems reasonable to conclude, therefore, that the *contrast concept* depends essentially upon differences expressed as a *ratio,* or in other words, upon *relative magnitude.*

Visual discrimination between the various parts of the retinal image of any object or collection of objects is based primarily upon differences in *color;* the word "color" being used in its broadest sense as including the factors of *hue, saturation* and *brilliance.* Visual perception of objects depends upon differences in these three attributes of color and the differences are frequently designated as *hue contrast, saturation contrast,* and *brilliance contrast.*†

The very nature of the present photographic process which produces, both in the negative and positive, a reproduction of the color differences existing in the object photographed only

† On page 20 of Parson's "An Introduction to the Study of Color Vision" (G. P. Putnam's Sons, 1915) will be found the following quotations:

"Our visual world consists essentially of differently presented colors: and objects as seen, that is visual objects, are nothing but colors of different nature and form." (Hering, 1905.)

"The eye sees no form inasmuch as light, shadow, and color together contribute that to which our vision distinguishes object from object and the parts of an object from each other." (Goethe, 1810.)

"All vision is color vision, for it is only by observing differences in color that we distinguish form." (Clerk Maxwell, 1871.)

as brightness differences makes it sufficient for the purpose of this paper to consider only the question of brilliance and brilliance differences.

Brilliance is defined [12] as " that attribute of any color by virtue of which it may be classed as equivalent to some member of a series of grays ranging between black and white."

Brilliance then may be considered to be the sensation (subjective) of which brightness is the stimulus (objective). Now the sensation is related in a definite way to the stimulus and the psychophysical law known as the Weber-Fechner Law states this relation as follows: " In order that differences of sensory experience, sensation, shall have in two different cases of comparison the same value for our reacting consciousness or shall appear to be equal, the stimulæ that are compared in the two cases must differ from one another not by the same absolute physical difference in their magnitude, but by the same relative difference."

It has been found that this law does not hold for the high and low extremes of stimulation, but is valid over a fairly wide range of the intermediate stimulus intensities. The form of the function relating stimulus and sensation has been determined experimentally over a wide brightness range by Nutting,[13] Blanchard,[14] Reeves [15] and others.

Contrast in Simple Two-part Field.—As a consequence of the psychophysical law stated above, it follows in the case of a two-part visual field, the brightness values (stimulæ) of which are represented by 1 and 2, that if a definite brilliance (sensation) difference is produced, then in another two-part field the same brilliance difference will be produced by brightness values of 2 and 4, or of 4 and 8, or of 8 and 16, etc. Thus if it is desired to build up a scale in which the brilliance increases by equal increments, that is, according to the series 1, 2, 3, 4, 5, etc., it will be necessary to make the brightness values increase not by equal increments, but according to the series 1, 2, 4, 8, 16, 32, etc. Now the logarithms of this brightness series are 0.3, .6, .9, 1.2, 1.5, etc., and it will be noted that this series of logarithmic values also increases by equal increments. Within the range, therefore, for which the above psychophysical law is valid, it may be said that the brilliance (sensation) is directly proportional to the logarithm of the brightness (stimulus). *Brightness contrast,*

therefore, may be defined numerically as the ratio of the brightness values; but "*brilliance contrast*" must be defined as the ratio of the brilliance values, or since brilliance is proportional to log brightness, as the logarithm of the ratio of the brightness values

$$\text{Brightness contrast (objective)} = \frac{B_1}{B_2}.$$

$$\text{Brilliance contrast (subjective)} = \log \frac{B_1}{B_2} = \log B_1 - \log B_2.$$

Objective Contrast in Complex Field.—The reasoning thus far applies only to the simplest of cases, the contrast between two areas of different brightness, and when an attempt is made to extend this to the more complicated cases met with in practice, many difficulties are encountered. It is usual to express the brightness contrast of an object by the ratio of the maximum brightness (B_0 max.) to the minimum brightness (B_0 min.). It should be pointed out that the word "object" is used throughout this paper as indicative of the entire ensemble in the visual field, or in the field of the photographic lens, and includes the entire group of objects which composes the scene or picture under discussion. For many purposes the use of the ratio of maximum to minimum brightness is entirely adequate, from the objective standpoint, as a means of expressing the contrast of such a complex group of brightness distributions. As an instance of this may be mentioned the usage of the term in photometry and illumination where the recognized definition of the word "contrast" is the ratio of the maximum to the minimum brightness.

Subjective Contrast in a Complex Field.—A careful analysis of the problem indicates that an analogous procedure in evaluating *subjective contrast* in the case of a complex brightness distribution is not adequate. There is little doubt that the word *contrast,* as used with respect to photographic materials, such as negatives and prints, refers to the subjective impression produced when these materials are viewed by the observer and hence it is with the subjective evaluation of contrast that we are vitally concerned. Since this is the case we must adopt the subjective method of expressing contrast, that is, in terms of the logarithms of the ratio rather than the ratio itself. Thus, if in the visual field consisting of a complex distribution of brightness values the

minimum brightness is designated as B_0 min. and the maximum brightness values by B_0 max., then the *subjective contrast* evaluated in a manner analogous to the usual method of expressing objective contrast would be in the form

$$\log \frac{B_0 \text{ max.}}{B_0 \text{ min.}} \text{ or } \log B_0 \text{ max.} - B_0 \text{ min.}$$

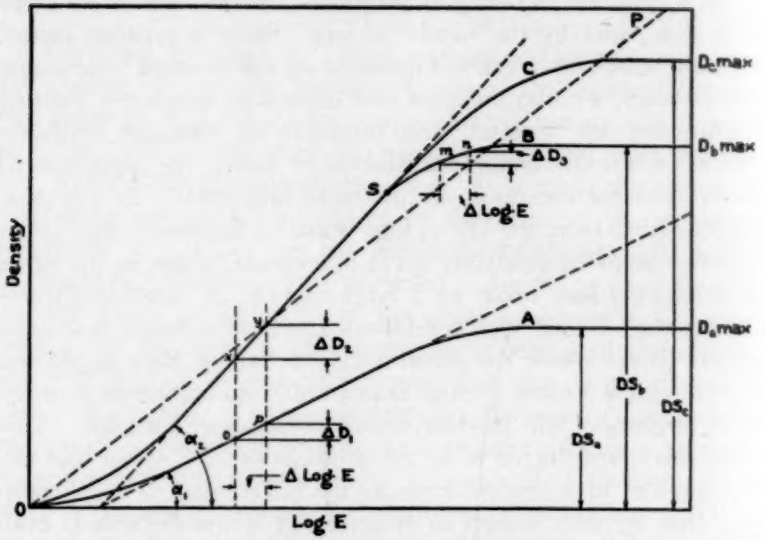
In a complex grouping of brightness values such as we refer to in this paper by the word "object," there is another factor, however, which has a marked influence on our contrast impression. For instance, we may imagine two objects in which the limiting brightnesses are identical and therefore of identical brilliance contrast when this factor is evaluated by taking the logarithm of the ratio of the maximum to minimum brightness. In one case, the transition from the low to high value of brightness may occur in a few steps of relatively great magnitude, while in the other the transition may occur by a large number of small brightness differences. Under such conditions a greater contrast will exist in that object where the transition from low to high brightness is rapid, while a more gradual transition from maximum to minimum brightness will produce an effect of lesser contrast. This factor may be referred to as the *gradient* or *rate* factor and can be expressed in a general form as the differential of log brightness ($\log B$) with respect to distance (s) where distance is evaluated in terms of visual angle, while the element of contrast previously referred to as dependent upon the value of $\log B$ max. – $\log B$ min. may be regarded as analogous to *range, extent* or *altitude.*

Contrast (subjective) is therefore a function of two independent variables, one of which may be referred to as the *rate* or *gradient* factor of contrast, and the other as the *extent* or *altitude* factor of contrast.

While analogies may sometimes be misleading if applied too literally, they frequently serve a useful purpose in establishing a comparative mental picture. The visual impression of contrast may be compared with the *muscular effort* involved in climbing a hill. This effort is proportional both to the *altitude* and to the *slope* or the *rate* at which the weight of the body is lifted. While the work involved in this operation is a function only of the mass and the height through which it is lifted, the muscular effort

involved depends very much on the rate at which the work must be done. Contrast may, therefore, be designated as the *visual effort* involved in perception of an object in which there are brightness differences and probably in the last analysis the magnitude of this visual effort, and hence of contrast, is propor-

FIG. 1.



Characteristic curves (density as a function of the logarithm of the exposure, Log E) for three photographic materials of different types.

tional to the intensity and surface distribution of the psychochemical reactions occurring in the retina.

The functional relations involved in the evaluation of contrast may be expressed in the general way as follows:

$$\text{Contrast} = f(\text{rate, extent})$$

$$\text{Extent} = f_1(\log B \text{ max.} - \log B \text{ min.})$$

$$\text{Rate} = f_2\left(\frac{d \log B}{ds}\right).$$

The correct evaluation of these functions should make it possible to compute the value of contrast for any specified brightness distribution in the visual field. While it is not necessary, for the solution of the contrast problem with which this paper deals, to complete the evaluation of these functions, their statement and the general understanding of them is of appreciable advantage in

establishing a sound fundamental basis on which to evaluate contrast as used with reference to photographic materials themselves.

Contrast in Relation to Photographic Materials.—We come now to a consideration of *contrast* when used in reference to photographic materials. It will be well to consider first the meaning of this word as applying to the materials themselves entirely independently of prints or negatives made thereon, and since the characteristic curves showing the relation between density and exposure are of the same general type for both negative and positive materials, it will be unnecessary in dealing with the fundamental relations to differentiate between these types. In Fig. 1 are shown three curves (of three different materials) which represent the general form of the density-log exposure function. Density in the case of silver deposits measured by transmitted light (negative, transparencies, etc.) is defined by the following relations:

F_0 = Luminous flux incident upon the silver deposit.
F_t = Luminous flux transmitted by the silver deposit.

$$T = \text{Transmission factor} = \frac{F_t}{F_0}.$$

O = Opacity.
D = Density.

$$D = \log O = \log \frac{1}{T} = \log \frac{F_0}{F_t}.$$

In the case of silver deposits on opaque reflecting surfaces (paper, etc.) density is specified in an analogous manner in terms of the diffusely reflected light.

F_0 = Luminous flux incident upon the deposit.
F_r = Luminous flux diffusely reflected by the deposit.

$$R = \text{Diffuse reflection factor} = \frac{F_r}{F_0}.$$

$$D_r = \log \frac{1}{R} = \log \frac{F_0}{F_r}.$$

If now a negative or print is viewed under uniform illumination, and it will be assumed that this is always the case, the resulting brightness values can be expressed in terms of density. Brightness is directly proportional to the transmission factors (or reflection factors) of the various areas on the negative (or positives), and since density is a logarithmic function of the

transmission factor, it follows that density is a logarithmic function of brightness. In expressing the brilliance contrast existing between two areas of a negative or print it is necessary, therefore, to specify only the density difference, $D_2 - D_1$, which is equivalent to the term $\log B_1 - \log B_2$ when the brilliance contrast is expressed in terms of brightness.

Referring now to Fig. 1, it will be seen in the case of curve B, at xy, that a given difference in exposure, $\Delta \log E$, is reproduced by the material whose characteristic is specified by this curve as a density difference ΔD_2, while with the other material (curve A), at op, the same exposure difference is reproduced as a density difference, ΔD_1. The ratios $\frac{\Delta D_2}{\Delta \log E}$ and $\frac{\Delta D_1}{\Delta \log E}$ represent the rate of change of density with exposure in the two cases and if these be reduced to infinitesimals the differentials $\frac{dD_1}{d \log E}$ and $\frac{dD_2}{d \log E}$ become the designations of these rates at particular points on the curve. The same exposure difference, $\Delta \log E$ rendered by material B at a different point (mn) gives a density difference ΔD_3, which is obviously less than the density difference ΔD_2. The value of $\frac{dD_3}{d \log E}$ is, therefore, less at this point on the curve and hence the material at that point has a lesser capacity for the reproduction of exposure differences than at the point xy.

The term *contrast* as applied to photographic materials must include some designation of their efficiency in reproducing exposure differences, for it is upon this characteristic that the possibility of reproducing brightness differences in the object as brightness differences in the negative or positive depends. A material which will render a small difference in exposure as a large difference in density is said to be *contrasty* or to have a high *contrast* value, while a material giving only a small density difference in response to a large exposure difference is said to be *flat* or lacking in contrast. The differential of density with respect to exposure, $\frac{dD}{d \log E}$, while it may not constitute a complete specification of contrast, certainly is an important factor in its determination; in fact, it is quite sufficient as a complete designation of contrast as a single point on the curve. However, since *contrast* is usually used with reference to the characteristic

of a material when its entire scale or a definite portion of the available scale is utilized, other factors must be considered.

That some factor other than the gradient must be included in contrast is forcibly illustrated by the following example. Referring again to Fig. 1, the curve designated as *C*, representing a third photographic material, has the same mean value of $\frac{dD}{d \log E}$ as the curve designated as *B;* in fact, the two characteristics are coincident up to the point indicated as *s*. Judged by the value of the differential $\frac{dD}{d \log E}$, these two materials are practically identical. The material *C*, however, has a higher value of maximum black, D_c max., and hence the density scale, DS_c, is greater than in the case of the materials *A* and *B*. It is possible on the material *C*, therefore, to produce negatives of greater *contrast* than on the material *B*, and if we assume that a positive material is available which will precisely reproduce the brightness distributions in the negatives, a *positive* of greater contrast can be obtained from the negatives made on the material *C*. The validity of this statement, of course, depends upon the assumption that the brightness contrast in the object is equal to, or greater than, the exposure scale of the material *C*. It is obvious, from a consideration of the curves *C* and *B*, that if the brightness contrast in the object being photographed is sufficiently small, identical negatives could be produced on the two materials. This fact, however, does not invalidate the statement that the material *C* has a greater capacity to render contrast than the material *B*. Consideration of these facts emphasizes the necessity of differentiating between contrast as applied to the materials themselves, and as applied to particular positives or negatives made thereon. It is probable that some modifying term must be attached to the word *contrast* in order to indicate in what sense it is used. For instance, some such term as *contrast capacity* or *total contrast* should be adopted when this term is used with reference to the contrast of the material itself.

It is evident from the reasoning thus far that contrast, as applied to photographic materials, is dependent upon two factors which may again be designated by the general terms *rate* (or *gradient*) and *range* (or *extent*), the former of these being dependent upon the differential of density with respect to log

exposure, while the latter is dependent upon the density scale (D max. $-$ D min.) available or utilized.

Contrast as relating to photographic materials may, therefore, be expressed in general form by the following function relations:

$$\text{Contrast} = f(\text{rate, extent})$$

$$\text{Rate} = f_1 \frac{dD}{d \log E}$$

$$\text{Extent} = f_2(D \text{ max.} - D \text{ min.})$$

The precise forms of these functions must be determined in order that we may arrive at a numerical expression of contrast. We shall consider first the evaluation of the extent function, and to do this we shall return temporarily to a consideration of the fundamental psychophysical law which states that the sensation is proportional to the logarithm of the stimulus. Within the range for which this law is valid, the least perceptible brightness difference, when expressed in terms of density, is constant. A constant density increment, therefore, corresponds to a constant decrement in sensation. The subjective sensation of contrast produced by two brightness values is directly proportional to the number of the least perceptible brightness steps between them, and if the least perceptible increment expressed in terms of density is $\triangle D$, it follows that contrast is directly proportional to the ratio $\frac{D \text{ max.} - D \text{ min.}}{\triangle D}$. We may, therefore, complete the evaluation of the *extent* factor in the following form:

$$\text{Extent} = c_1(D \text{ max.} - D \text{ min.})$$

where c_1 is the constant of proportionality depending upon the absolute value of $\triangle D$, assuming that $\triangle D$ is constant throughout the brightness range considered.

In case $\triangle D$ is not constant it is still possible to evaluate the *extent* factor of contrast, provided the contrast sensibility function of the eye is known for the particular range of brightness values involved. This function has been determined [13, 14, 15] and hence is available for use if necessary. We shall, however, throughout the treatment of this subject, make the assumption that the brightness values dealt with are such that the value of $\triangle D$ is constant, and the evaluation of the extent factor of contrast expressed above will be used.

It remains now to deal with the *rate* factor. The rate com-

ponent of contrast is some function of $\frac{dD}{d \log E}$, but it is necessary to base its quantitative evaluation upon the magnitude of the least perceptible brightness difference, or its equivalent, the least perceptible density difference, $\triangle D$. Let $\triangle \log E$ represent the exposure difference which corresponds to the least perceptible density difference $\triangle D$. It is evident that the relation between the magnitudes of these two values is directly dependent upon the slope of the characteristic curve, $\frac{dD}{d \log E}$. The *rate* factor of contrast is inversely proportional to the magnitude of $\triangle \log E$, and $\triangle \log E$ is inversely proportional to $\frac{dD}{d \log E}$ at the point on the characteristic curve being considered. *Rate* is, therefore, directly proportional to $\frac{dD}{d \log E}$, and we may write as its evaluation:

$$\text{Rate} = c_2 \left(\frac{dD}{d \log E} \right)$$

where c_2 is the constant of proportionality depending for its absolute magnitude upon the value of $\triangle D$. The constants of proportionality, c_1 and c_2, both depend upon the value of the least perceptible brightness difference, and if the value of this term, $\triangle D$ (over the range of brightness values being considered) is known, it is now possible to evaluate contrast in absolute terms. In general, however, it is neither necessary nor desirable to attempt the expression of contrast in this manner. It is quite adequate to neglect the constants of proportionality and specify contrast in relative terms as the product of the rate and extent factors.

The relations may be summarized as follows:

$$\mathfrak{E} = \textit{extent} = c_1 (D \text{ max.} - D \text{ min.})$$

$$\tau = \textit{rate} = c_2 \left(\frac{dD}{d \log E} \right)$$

$$\Omega = \textit{contrast} = c_3 (\mathfrak{E} \cdot \tau) = c_3 (D \text{ max.} - D \text{ min.}) \cdot \left(\frac{dD}{d \log E} \right).$$

IV. OUTLINE OF SENSITOMETRIC METHOD.

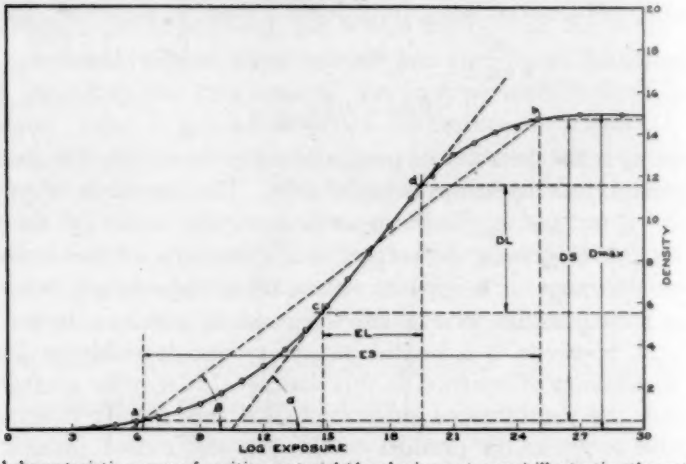
A complete knowledge of the properties of any photographic paper may be obtained by sensitometric measurements as outlined in the previous communication.[1] It was pointed out in that article that the quality of a photographic paper can be completely specified only by the entire characteristic curve obtained from plotting density (D) as a function of the logarithm of the exposure

(log E). It was shown, however, that the behavior of a paper can be fairly well represented by a few numerical constants, each of which refers to some specific characteristic of the paper. The constants proposed for this purpose at that time were:

(1) Maximum density (D max.).
(2) The slope of the straight line portion (γ).
(3) Total scale (S).
(4) Latitude (L).
(5) Rendering power (R).
(6) Standard exposure (E_s).

All of these constants except the last (E_s) are involved

FIG. 2.



Typical characteristic curves of positive material (developing-out paper) illustrating the method of determining the various numerical values referred to as sensitometric constants.

to a certain extent in the evaluation of contrast. Rendering power, however, is derived from total scale and latitude, and hence is a dependent variable. Information gained since the publication of the communication indicates that the constants proposed at that time are not entirely adequate for the determination of contrast. In the case of many photographic materials, especially printing papers, the proportion of the characteristic curve which is a straight line is so small that the value of γ is not a satisfactory specification of the gradient characteristic. It is necessary to evaluate the gradient, $\frac{dD}{d \log E}$, in order to obtain the mean effective value of gradient for the entire curve, or for

that portion that is utilized in any particular case. For the purposes of contrast and tone reproduction problems it has been found advantageous to extend somewhat the analysis of the characteristic curve and to define other values than those proposed previously. These are illustrated in Fig. 2, in which is shown the characteristic curve of a typical developing-out paper of average or normal *contrast.*

The points a and b are located on the characteristic curve where the gradient $\frac{dD}{d \log E} = .2$; the points c and d are located at the limits of the straight line portion. It may be well at this point to make a general statement in regard to this so-called straight line portion. From the theoretical standpoint it is doubtful whether any part of the characteristic curve should be regarded as a straight line. It has been found, however, from experience based on thousands of such curves, that there is usually a portion of the characteristic curve which, to within the limits of experimental observation, is a straight line; and for many purposes it is useful to regard this portion as a true straight line, the slope of which is designated by the tangent of the angle between the straight line and the exposure axis, $\tan \alpha = \gamma$.

Now let the exposure (E) and the density (D) values applying to the point a be designated by the subscript a; those to point b by the subscript b, etc. The values which have been found useful in the computation of contrast and in the correlation of sensitometric results with practical and statistical data are given below. The nomenclature and symbols adopted in designating these quantities are in conformity with the systematic scheme proposed previously,[24, 26, 31] for use in problems of photographic sensitometry and tone reproduction.

DS_y = density scale = $D_b - D_a$.
DL_y = density latitude = $D_d - D_c$.
ES_y = exposure scale = log E_d − log E_a.
EL_y = exposure latitude = log E_d − log E_c.

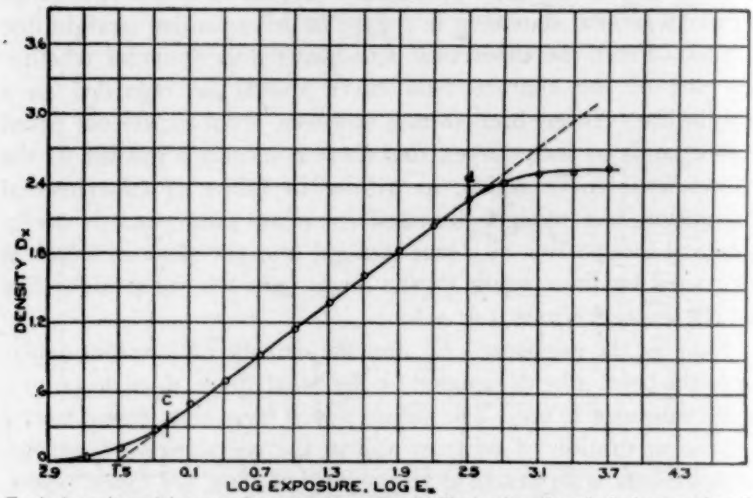
γ_y = gamma = $\frac{DL_y}{EL_y}$ = maximum gradient.

ϕ_y = phi = $\frac{DS_y}{ES_y}$ = mean gradient between points a and b.

$D_y$max. = maximum density.

The terms given above apply specifically to a positive material, as is designated by the subscript y. Similar values applying to negative materials may be determined in precisely the same way, except that the density values are measured by transmitted rather than reflected light. These values when applying to a negative material are designated by the subscript x. Since the value of the gradient $\frac{dD}{d \log E}$ varies from point to point on the characteristic curve, being constant only for the straight line region, it follows that if this value is to be used in the compu-

FIG. 3.



Typical sensitometric curve for a negative material illustrating the relatively great length of straight line portion usually found in such materials.

tation of contrast some method must be provided for determining its mean effective value. This applies to both negative and positive materials if it is desired to express the *total contrast* or the *contrast capacity* of the material. In general it is not of great importance to determine this for negative materials since the total range of density available in these materials is rarely utilized.

Similarity in shape between the characteristics of negative and positive materials is seen by comparison of the curve in Fig. 2 with that in Fig. 3, which is the characteristic curve of a typical negative material. It will be noted, however, that in the case of a negative material a much greater maximum density is obtained and that the total scale is much greater, being approximately 4.2,

while that of the positive material shown is only 2.0. The exposure latitude in the case of the negative material is also very much greater, being 2.7, as compared with .5 for the positive material. These values are given in logarithmic terms, and converting back to numbers we see that the negative material illustrated in Fig. 3 is capable of rendering, on the straight line portion, an object having a brightness scale (BS_0) of 500. For this portion of the negative curve the value of $\frac{dD}{d \log E}$ is constant and hence the evaluation of the rate factor of contrast is very simple. As a matter of fact it is almost always possible to render the entire brightness scale of an object on the straight line portion of a negative material. From a large number of brightness measurements made on objects of various kinds, it has been found that the brightness scale met with in practice rarely exceeds 250. The normal landscape has a brightness scale of approximately 40 or 50. Flat landscapes, such as that containing large proportions of water and snow scenes, may have a brightness scale as low as from 4 to 10. In rare cases of natural objects, such as those including white clouds and shadows under trees or within buildings, a brightness scale of from 500 to 1000 may be found. In the portrait studio the scale of the object seldom exceeds 50 or 100 and on the average is much lower. It is evident, therefore, that in the great majority of cases the brightness scale of the object can be rendered entirely on the straight line portion of the negative material. This, of course, is true only when sufficient exposure is given to render the deepest shadow (lowest brightness) by a density sufficiently great to put it upon the straight line portion. While it is true that this is not done in a large percentage of negatives made for practical purposes, nevertheless it can be done if it is necessary or desirable to obtain precise proportional tone reproduction in the negative.

This condition, however, does not exist in the case of positive materials, such as developing-out papers. It is usually necessary to utilize the entire density scale available in order to produce the best approximation to true reproduction. In the case of these materials we are, therefore, faced with the necessity of determining the mean effective value of $\frac{dD}{d \log E}$ for the major portion of the characteristic curve, including not only the straight line, but the regions of variable gradient. It is evident that the mean

effective value of gradient will depend upon just how much of the curve is utilized and hence it is necessary to provide some method of determining the useful portion of the positive material before it is possible to compute the value of contrast applicable in the particular case under consideration.

In the previous communication (*loc. cit.*) on this subject the points on the characteristic curve at which $\frac{dD}{d \log E} = .2$, were chosen as the limits of useful exposure scale. A more complete knowledge of conditions required for satisfactory tone reproduction makes it evident that only for certain combinations of object brightness scale (BS_0) with negative gradient (γ_n) is it possible for these values to represent the limits of utilizable scale. The value of the positive material gradient at the limits of the useful scale varies widely under different conditions and hence, if it is desired to evaluate the contrast of that portion of a positive material which is available for the reproduction of any particular object brightness scale (BS_0), some means must be found for determining just exactly what portions of the positive material curve can be utilized. At the time this work was initiated there seemed to be no direct sensitometric method for the determination of this, and it was necessary to resort to a statistical method.

V. OUTLINE OF STATISTICAL METHOD.

Since the gradient of the negative material can be controlled over a fairly wide range by variation in the time of development, it is possible on a given material to obtain a series of negatives of the same object in which the magnitude of the density scale is variable. Furthermore, since the brightness scale of the average object can be rendered entirely on the straight line portion of the negative material, the gradient $\frac{dD}{d \log E}$ of each negative will be constant and hence can be specified by the single numerical value (γ_n). From the requirements of tone reproduction it is evident that the density scale of the negative (DS_n) must be equivalent to the exposure scale of the positive (ES_p). In such a series of negatives, since they are all of the same object, and BS_0 is, therefore, constant, the variation in the density scale of the negative is directly proportional to the gamma of the negative (γ_n).

In making prints from this series of negatives, it will be

necessary to use printing papers of different contrast characteristics in order to obtain satisfactory prints from all of the negatives, and, by a method of trial and error, it will be possible to determine for any given printing-out paper which negative will give the most satisfactory print. From a knowledge of the density scale of the negative giving the best print, we can then determine for that printing paper just what portion of the characteristic curve is useful for the reproduction of that particular object under consideration. We can then proceed with the evaluation of the mean effective gradient for the portion of the positive curve utilized, and hence obtain a series of contrast values for various papers.

This method for the determination of the useful portion of the characteristic curves involves a decision as to the negative best suited to the paper and the measurement of the gamma and density scale of the negative used. The measurement of the γ_n and DS_n of the negative is easily accomplished by the usual sensitometric methods, and their values can be determined with fairly high precision. The determination of the negative best suited to the paper is accomplished by making several prints on the paper under consideration from a group of negatives developed to slightly different extents, and subsequently choosing the print which shows the best quality.

The judgment of print quality involves the personal equation, and may vary to some extent, depending upon the experience and training of the individual making the choice. In order to obtain a representative value, it is necessary, therefore, to obtain the judgment of a large number of individuals and by averaging the results, arrive at a mean from which the most probable contrast value of a paper may be computed. Due to the necessity of basing the final value on the average of a large number of personal judgments, this method is of a statistical nature and in contradistinction to the *sensitometric* method which involves only the making of physical measurements; it will be referred to in this paper as the *statistical method.*

VI. TONE REPRODUCTION THEORY.

The problem of contrast is but a special case of the more general problem commonly referred to in the literature of photography as *tone reproduction.* In the correlation of the results

derived from the statistical and sensitometric study of this problem, it will be necessary to refer frequently to tone reproduction relationships. It will be advantageous at this time, therefore, to present a brief résumé of the theory of tone reproduction, and to explain the methods whereby the exactness of reproduction obtainable, when using specified negative and positive materials, can be determined.

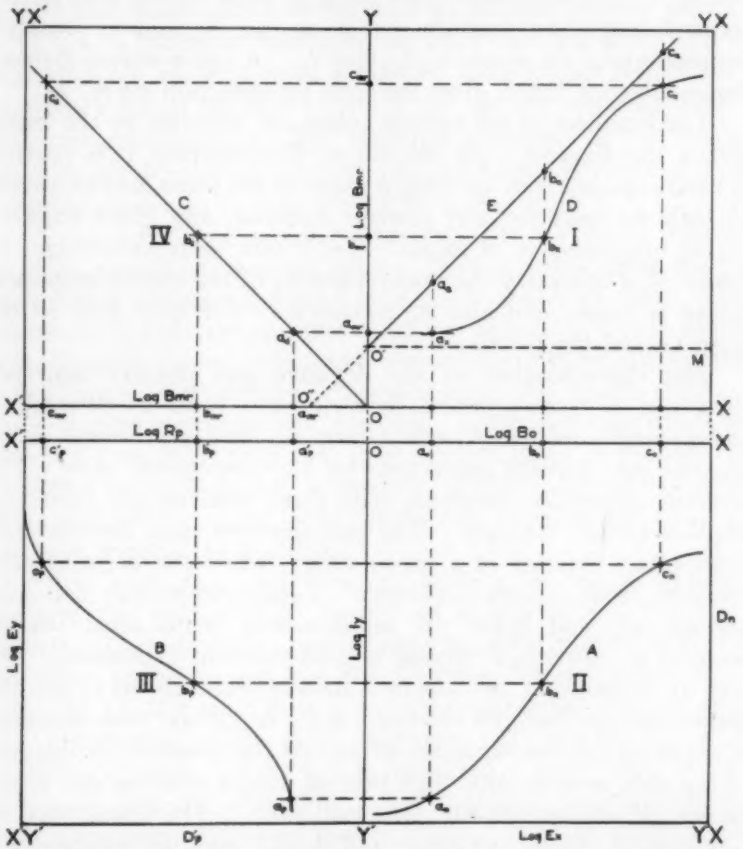
Many papers have been written on this subject and for a complete detailed treatment the reader is referred to the previous publication.[24] Hurter and Duffield,[16] who may be considered to be the founders of the science of photographic sensitometry, dealt with this subject to a certain extent. Since that time many other papers have appeared, among which may be mentioned those by Lord Rayleigh,[17] Renwick,[18, 19, 21, 23] Porter and Slade,[20, 22] Jones,[24, 25, 26] and Mees.[30]

The paper by Mees contains an excellent review of the entire subject of tone reproduction, especially from the standpoint of its application to practical problems. The problem of *contrast* was also considered briefly and some of the results derived from this study of the contrast problem were given. His paper was prepared before the final conclusions relative to the method for evaluating contrast were drawn, and while the work which has been done since that time has made it necessary to modify certain details of procedure, the general conclusions relative to contrast and to the relation between negative and print quality are substantially as stated at that time.

In the previous papers by the author,[24, 25, 26] a graphic solution of the tone reproduction problem was presented. In Fig. 4 is shown the tone reproduction diagrams. Along the axis OX is established the logarithmic scale of brightness upon which the brightness values of various object areas may be plotted. The curve A in quadrant II is the usual characteristic curve of the negative material. The curve B in quadrant III is the characteristic curve of a positive material. The curve in quadrant IV is a straight line, 45° at the axis, and passes through the origin; it is used when only the objective phase of the tone reproduction problem is being considered. Curve D in quadrant I is the reproduction curve, and its shape and position indicate the truthfulness with which the visual brightnesses of the object are reproduced in the positive. Curve E in quadrant I, which is a straight line at

45° at the axis, and whose position is determined by the magnitude of the illumination under which the positive is viewed, is the curve of exact tone reproduction. The magnitude of the departures of curve *D* (both with respect to shape and position) gives

FIG. 4.



The tone reproduction diagram. This illustrates the method used in obtaining a quantitative determination of the quality of tone reproduction with any specified negative and positive material.

a quantitative measure of the failure of the process to reproduce precisely the scale of visual object brightnesses. The method of plotting curve *D* is illustrated by the dotted lines in the figure. The points a_0, b_0, and c_0 represent the visual brightnesses of areas in the object being photographed. Perpendiculars from

these points are dropped; where they intersect curve A, the points a_n, b_n, and c_n are located. Horizontal lines through these points locate the points a_p, b_p, and c_p on the characteristic curve of the positive material. Perpendiculars from these points intersecting the curve C in quadrant IV establish the position of points c_d, b_d, and a_d. The horizontal lines through these points intersecting perpendicular lines through the points a_0, b_0, and c_0 establish the position of the points a_x, b_x, and c_x. A curve drawn through the points thus found gives the tone reproduction curve, D.

The locations of the various scales are indicated by the lettering on the diagram. By the use of this diagram, it is possible to determine precisely on what portion of the characteristic curves of both the negative and positive material, any given scale of object brightness is rendered. To obtain such knowledge, of course, it is necessary that measurements of the object brightness values be made, and also measurements of density both in the negative and the positive.

The characteristics of the negative and positive materials must also be known; these characteristics must be determined *under conditions which will assure the true representation of negative and positive characteristics by sensitometric data.* The necessity of rigidly complying with these requirements cannot be emphasized too strongly. The sensitometric data are obtained from plates exposed in a sensitometer, while the negatives are obtained from camera exposures. Camera exposures are *non-intermittent,* and hence the sensitometric strips must not be made in an instrument giving non-intermittent exposures. The time of exposure in the camera is usually relatively short and the illumination on the plate relatively high, hence care must be taken in exposing the sensitometric strips that the illumination incident on the plate is sufficiently high that no danger of error due to the *failure of the reciprocity law* can exist. The conditions of *development, fixing, washing,* and *drying* must be identical for both the sensitometric strips and negatives.

One other point that must be carefully considered is that of the way in which the density values are measured. The silver deposit forming the image consists of fine particles of metallic silver embedded in a matrix of gelatin. This deposit, therefore, scatters the light which is transmitted. In contact printing all of the transmitted light is effective in producing exposure on the

positive material, and hence, for contact printing it is necessary to express the absorbing power of the negative in terms of diffuse density. If the negatives are to be used for enlargement, or to be printed by projection, then only the light which is specularly transmitted is effective in producing exposure on positive material. Under such conditions it is the value of specular density which is required. Care must, therefore, be taken that the density measurements are made in such a manner as to obtain the effective printing value of the density which will depend upon the method of making the positive. For complete treatment of the relation between *diffuse* and *specular density* the reader is referred to an excellent treatment of this subject by Callier.[32, 33, 40]

Some developers produce silver deposits which are *selective* in their absorbing characteristics. This is particularly true of pyro which produces a deposit appreciably yellow in color. Now positive materials are sensitive chiefly to radiations of the shorter wave-lengths (blue, violet, and ultra-violet), while the eye has a maximum of sensitivity in the middle of the visible region at wave-lengths approximately 550 $m\mu$. Silver deposits which are *selective* (colored), therefore, may have an absorbing power, for radiation to which the eye is sensitive, radically different from the absorbing power of the same deposit for radiation to which the positive material is sensitive.

It is necessary, therefore, in some cases, to differentiate between the *photographic density* of a deposit and the *visual density*. Care must be taken in applying tone reproduction relationships, to be certain that the negative density values are in terms of *photographic density* as evaluated by the positive material being used. The same reasoning, of course, applies to brightness values. Such values measured visually may be very different from the analogous values measured photographically, and in the case of colored objects, account must be taken of this factor. In this paper *photographic* and *visual* values are differentiated by v (visual) and p (photographic) placed in parenthesis after the value or symbol used for its designation, thus

$D_n(v)$ = Negative density evaluated visually.
$D_n(p)$ = Negative density evaluated photographically.

The subjective phase of the tone reproduction problem was dealt with also,[24] and a method of computing the effect of sub-

jective factors (such as differences in the adaptation level of the observer's eye) was developed. In the present work no attempt will be made to treat this phase of this subject in its relation to contrast. This will permit a slight simplification of the symbols used, since it will not be necessary to differentiate between the characteristics of the subjective (SR) and the material reproduction (MR). Terms relative to the reproduction curve will be indicated, therefore, by the subscript r.

Some of the more important relationships between the various factors are given below:

For the straight line portions of the curves,

$$\gamma_n \cdot \gamma_p = \gamma_r .$$

At the corresponding points on the three curves,

$$\frac{dD_n}{d \log E_x} \cdot \frac{dD_p}{d \log E_y} = \frac{d \log B_r}{d \log B_0}$$

$$G_n \cdot G_p = G_r .$$

For exact tone reproduction,

$$G_r = 1.0 = \text{a constant.}$$

From these relationships it follows that

$$\frac{DS_n}{ES_n} \cdot \frac{DS_p}{ES_p} = \frac{BS_r}{BS_0}$$

and

$$\phi_n \cdot \phi_p = \phi_r .$$

VII. RÉSUMÉ OF NOMENCLATURE, SYMBOLS, DEFINITIONS, ETC.

The reader will realize from a consideration of the material thus far presented that there are many factors involved in this problem, and in order to avoid confusion it is essential that a logically and clearly defined system of nomenclature be adopted.

In the papers already referred to [24, 25, 26] a system of terminology and symbols for representing the various factors in the tone reproduction problem was presented, and it is proposed in this paper to follow as nearly as possible the nomenclature established at the time. There are, however, certain added factors which have arisen in the work on contrast that make it necessary to add new terms, and the nomenclature must be expanded to include these.

The materials or *things* involved are essentially the same as in

the tone reproduction work and are tabulated below with the symbols by which they are designated.

O	.....Object.
X	.....Negative sensitive material.
N	.....Negative.
Y	.....Positive sensitive material.
P	.....Positive.
SR	.....Subjective reproduction.
MR	.....Material reproduction.

In this paper no attempt will be made to deal with the subjective phase of tone reproduction. It will be unnecessary, therefore, to distinguish between the *subjective reproduction, SR,* and the *material reproduction, MR.* It will be satisfactory, therefore, to use the single symbol *R* as indicative of the *reproduction,* and this letter used as a subscript attached to the symbols indicating the various attributes, will indicate that they apply to the *reproduction.* It should be kept in mind at all times, however, that there is a possibility of subjective factors having a marked influence on the actual contrast values as they apply to practical work. For instance, if a positive is viewed under an illumination such as to give brightness values differing greatly from those existing in the object, the effective contrast may be markedly different from that indicated by a purely objective treatment of the subject. A reproduction of a brilliantly illuminated scene, such as an open landscape in sunlight, if viewed under very low illuminations, may produce a subjective contrast obviously too low even though the objective measurements indicate a precise reproduction of contrast.

The various terms and physical factors which may be applied as descriptive of, or to indicate some characteristics of these things, are given in Table I.

TABLE I.

F_0 = Luminous flux incident upon the silver deposit.
F_t = Luminous flux transmitted by the silver deposit.
F_r = Luminous flux diffusely reflected by the silver deposit.
N = Illumination (expressed in millilamberts, ml.).
B = Brightness (expressed in metre-candles, mc.).

R = Reflection factor = $\frac{F_r}{F_0}$.

T = Transmission factor = $\frac{F_t}{F_0}$.

TABLE I—*Continued.*

t = Time (in seconds).
E = Exposure (in metre-candle seconds, mcs.).
O = Opacity = $\frac{1}{T} = \frac{F_0}{F_t}$.
D = Density = log o = log $\frac{1}{T}$ = log $\frac{F_0}{F_t}$ = log $\frac{1}{R}$ = log $\frac{F_0}{F_\gamma}$.
BS = Brightness scale.
DS = Density scale.
ES = Exposure scale.
DL = Density latitude.
EL = Exposure latitude.
G = Gradient at any point on characteristic curve, $\frac{dD}{d \log E}$.
γ = Gradient of straight line portion of characteristic curve.
ϕ = Mean gradient between specified points on characteristic curve.
θ = Equalized limiting gradient.
Δ = Finite increment in factor to which it is prefixed.
χ = Color coefficient.
Ω = Contrast.
r = Rate factor of contrast.
ε = Extent factor of contrast.

(To Be Continued.)

Permanent Paint for Iron Discovered by Swiss. (*Science News-Letter*, **9**, No. 273, July 3, 1926.)—The annual loss to the world due to the rusting of iron runs into many millions of dollars, and the problem of its prevention is being studied by scientists in all civilized countries. Zinc, tin, nickel, ordinary lead paint and many other things are useful preventives, but they do not last, and have to be re-applied more or less frequently.

A remarkable discovery is now announced from Switzerland. Dr. A. V. Blom, of Berne, has made a new lead paint which affords complete and permanent protection to iron. This paint is of a very special character; it is made by melting lead in an electric furnace and blowing through it air and certain reducing gases, so that a dross or scale is produced which consists of colloidal or extremely finely divided lead dispersed in yellow lead oxide. When it is powdered and mixed with a specially prepared linseed oil, and applied to an iron surface, very minute particles of lead separate out and gradually penetrate into the surface of the iron. The presence of the lead in the treated iron has been proved by photomicrographs and by chemical analysis. Iron objects painted with this new pigment have not shown any signs of rusting after prolonged exposure, or after being heated in steam. This discovery may lead to extremely important developments. R.

NOTE ON RIBBON LIGHTNING.*

BY

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Meteorological Physicist, U. S. Weather Bureau; Associate Editor.

THE well-known "ribbon lightning" is a more or less continuous discharge along the same lightning path for an appreciable length of time. When it is photographed with a moving camera, a ribbon-like picture is obtained with narrow cross-stripes; hence the descriptive name. Often, there are lengthwise stripes also,

FIG. 1.

producing a plaid effect, due no doubt to variations in the strength of the current.

The cross-stripes have been attributed to portions of the path approximately in the line of sight, and therefore exceptionally bright. Such sections of the path would undoubtedly produce bright stripes, both visual and photographic, of the kind observed. However, they may have an entirely different origin, as illustrated in Fig. 1, a lightning picture taken with a hand camera by Gordon J. Platt. The broad bands of light were accidental and extraneous.

* Communicated by the Author.

It will be noted that: (*a*) All bends along the path of the main discharge trunk that lie in a given direction are brighter than any other portions and prolonged across the ribbon.

(*b*) The longer the bend, the brighter it is and the brighter its extension.

(*c*) The nearer any portion of the extended line parallels the bend, the brighter that portion appears.

(*d*) The greater the difference between the directions of the path and the bright cross-stripes, the fainter both the ribbon and its initial border.

(*e*) The lightning was brightest at the beginning and faded away slowly with but little if any sudden fluctuations in intensity.

From the above it is obvious that the camera was moved parallel to the cross-stripes, each of which therefore is the result of overlapping images of the lightning bend from which it springs. Furthermore, where the line-of-sight effects are equal, or, neglecting the line-of-sight effect, the brightness of any portion of the ribbon is proportional, approximately, to $f/\sin a$, in which a is the angle between the direction of motion of camera and the straight, or nearly straight, section l of the lightning path that produced the portion of the ribbon under consideration, and f the brightness of the ribbon where a is 90°.

There are, then, two causes of the bright cross-stripes in ribbon lightning, usually more or less combined: (1) Line-of-sight direction of portions of the path, giving the intensified end-on effects; (2) movement of the eye, or camera, parallel to sections of the streak, causing superposition, hence intensification, of their images.

Doubtless this also is the explanation of beaded lightning, a streak of disconnected spots and dashes.

Preservation of Colorimetric Standards for the Determination of Hydrogen-ion Concentration.—SYDNEY L. WRIGHT, JR. (*Bull. Ayer Clinical Lab. Penna. Hosp.*, 1925, **9**, 63–64), has found that standard solutions of known hydrogen-ion concentration (pH) may be preserved for periods as long as eighteen months with a fair degree of success, provided they be sealed in glass tubes, then sterilized at a pressure of 15 pounds. These solutions are prepared by addition of a suitable indicator, such as phenol red or bromthymol blue, to a buffer solution such as a phosphate mixture of definite composition. J. S. H.

THE FRANKLIN INSTITUTE.

MEDAL DAY MEETING.

THE formal minutes of the Medal Day meeting, held on May twelfth, were printed in the June number of the JOURNAL. The special exercises in connection with the award of the Medals and the papers presented, are described in the following sections:

Award of the Longstreth Medal.

To Mr. James John Denny, MacIntyre Porcupine Mines, Ltd.

Mr. H. H. Quimby, sponsor for Mr. Denny, said: "Mr. President, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. James J. Denny, of Ontario, Canada, as the recipient of the Longstreth Medal, in consideration of the successful application of a rubber lining to rotary grinding mills which he has perfected.

"In the absence of Mr. Denny, I present Mr. Watson, the British Consul General, who will receive the Medal for him."

Doctor Eglin then presented the Medal to Mr. Watson with the statement: "Mr. Watson, as President of The Franklin Institute, it is my pleasure to present to you the Longstreth Medal for transmission to Mr. Denny, and also a copy of the certificate and a copy of the report of the Committee on Science and the Arts."

The Secretary read a portion of a letter from Mr. Denny, as follows: "It is my sincere wish that you inform the President of The Franklin Institute and the Committee on Science and the Arts, that I will gladly accept this medal, and convey to them my appreciation for the honor they have bestowed upon me."

Award of the Wetherill Medals.

To Mr. Frank Twyman, F.R.S., F. Inst. P., Managing Director, Adam Hilger, Ltd.

To the Wagner Electric Corporation, represented by Mr. E. W. Goldschmidt.

Dr. James Barnes, sponsor for Mr. Twyman, said that the award was made by the Committee on Science and the Arts "in consideration of the great scientific value of his interferometer for the testing of optical parts."

In the absence of Mr. Twyman, he then presented the British Consul General, who received the Medal for Mr. Twyman.

In presenting the Medal, Doctor Eglin said: "Mr. Watson, as President of The Franklin Institute, it is my pleasure to present to you the Wetherill Medal for transmission to Mr. Twyman, and also a copy of the certificate and a copy of the report of the Committee on Science and the Arts."

The Secretary read the following message from Mr. Twyman: "I have to thank you for your letter of January twenty-first, in which I note with the deepest gratification that the Sub-committee of your Science and Arts Committee has recommended the award to me of the Institute's John Price Wetherill Medal for my interferometer. The award of the medal will be a source to me of the very greatest encouragement and very great pleasure."

Mr. H. H. Calvert, sponsor for the Wagner Electric Corporation, was next recognized by the President, and said: "Mr. President, I have much pleasure in presenting to you upon recommendation of the Committee on Science and the Arts, the Wagner Electric Corporation, through its representative, Mr. E. W. Goldschmidt, as the recipient of a John Price Wetherill Medal, with special mention of Val A. Fynn and H. Weichsel, in consideration of the progress in the electric art which their invention marks, and in consideration of the development of a motor of excellent design and construction and one which is in successful use."

In making the award the President said: "Mr. Goldschmidt, as President of The Franklin Institute, I have much pleasure in presenting to you the Wetherill Medal and also a copy of the certificate and a copy of the report of the Committee on Science and the Arts, with the hope that it may encourage you and those connected with the Research Department of your Company to continue in the work which you are now carrying on."

Award of the Levy Medals.

To Mr. Frank W. Peek, Jr., General Electric Company.

To Prof. Ernest G. Coker, D.Sc., F.R.S.E., University of London.

Dr. H. J. Creighton, sponsor for Mr. Peek, presented him with the statement that the award was recommended because of his paper which appeared in the February, 1925, issue of the JOURNAL OF THE FRANKLIN INSTITUTE, entitled "Lightning."

In presenting the Medal to Mr. Peek, Doctor Eglin said: "As President of The Franklin Institute, it is an especial pleasure to

present to you the Levy Medal for the excellent paper which appeared in the JOURNAL OF THE FRANKLIN INSTITUTE. This paper adds greatly to our knowledge on the subject, and through its publication in the JOURNAL has reached those who are interested in such work. It is particularly pleasing to us to recognize this work which you have done by presenting to you this Medal."

Doctor Creighton, also sponsor for Professor Coker, informed the meeting that the award was made for a paper by Professor Coker which appeared in the March, 1925, issue of the JOURNAL OF THE FRANKLIN INSTITUTE, entitled "Photo-elasticity." In the absence of Professor Coker, he then presented the British Consul General to receive the Medal.

Doctor Eglin presented the Medal as follows: "Mr. Watson, as President of The Franklin Institute, it gives me great pleasure to convey to you the Levy Medal to be transmitted to Professor Coker in London, for his valuable paper which was lately published in the JOURNAL OF THE FRANKLIN INSTITUTE on the investigation of complex structures. It gives me much pleasure to hand you this Medal."

In accepting the Medal Mr. Watson said: "It gives me a great pleasure to act as proxy to my distinguished countrymen in receiving these Medals which you have bestowed upon them. I only wish that my own attainments were such that I might hope to receive a medal some day myself, and not by proxy."

The Secretary read the following letter from Professor Coker: "It was an exceedingly pleasant surprise for me when I returned home from my Easter holidays to find your most kind letter conveying the very gratifying news of the award of a Louis Edward Levy Medal.

"Will you kindly convey to the President and Council of The Franklin Institute my very warm appreciation of the great honour they have conferred upon me, and also my sincere regret that my duties here prevent my coming to the Institute on May twelfth to receive the Medal and Certificate in person.

"Again my very hearty thanks for this most kind and unexpected distinction."

Award of the Cresson Medals.

To George Ellery Hale, Ph.D., D.Sc., LL.D., Honorary Director, Mount Wilson Observatory.

To Charles Sheldon Hastings, Ph.D., Professor Emeritus of Physics, Yale University.

Prof. W. O. Sawtelle, sponsor for Doctor Hale, said that the award was made "in consideration of his outstanding researches and discoveries relating to the sun and the solar atmosphere and to solar physics."

Doctor Eglin stated that Doctor Hale could not be at the meeting because of ill health, and in his absence the Medal was turned over to the Secretary of the Institute, for forwarding to Doctor Hale.

The Secretary read the following letter from Doctor Hale: ".I heartily appreciate the action of The Franklin Institute in awarding me the Elliott Cresson Medal, a distinction which I shall highly prize. Needless to say, it would be a great pleasure to attend the presentation exercises and dinner on May twelfth. I fear, however, that it will be necessary for me to return to Pasadena before that time. Even if I find it possible to remain here, I cannot hope to take any active part in the ceremonies on account of the persistent illness which forced me to resign the directorship of the Mount Wilson Observatory.

"I want you to realize that I am not lightly avoiding the kind invitation you give me. I appreciate it so sincerely that under normal circumstances I would gladly cross the continent to accept it."

Dr. G. S. Crampton presented Prof. Charles Sheldon Hastings as the recipient of the Cresson Medal "in consideration of his scientific attainments and of his originality and skill in the design and computation of optical systems of the highest order, and in recognition of his life work as a man of science who sought not the light for his own illuminating."

In addressing Professor Hastings, Doctor Eglin said: "Professor Hastings, it is an especial pleasure for The Franklin Institute to recognize your life work in the study of optical instruments and the development of optical lenses, and it gives us great pleasure to present to you the Elliott Cresson Medal and the certificate and copy of the report of the Committee on Science and the Arts which accompany it."

Award of the Franklin Medal and *Certificate of Honorary Membership.*

To Prof. Niels Bohr, Ph.D., Director of the Institute for Theoretical Physics, Copenhagen, Denmark.

Prof. W. F. G. Swann, of Yale University, in presenting Professor Bohr, made the following interesting statements:

"Mr. President: There are times in the growth of human thought when nature, having led man to the hope that he may understand her glories, turns for a time capricious and mockingly challenges his power to harmonize her mysteries by revealing new treasures which find no place in his scheme of understanding and violate all his cherished traditions as to what he might have expected from her.

"Those who have grown old in building the framework of thought in whose setting so much of nature has been rendered clear, hesitate to tamper with that frame. Bold, and even radical in their youth, they become conservative with age; and as a great statesman stands in awe of the constitution he has helped to build, fearful that the slightest change may bring dire results, so even the giants of science become timid in speculation and it is often to genius in its youth that the world must turn to decipher the harmonies in the new composition and mould them with time into such uniformity with each other and with the past that the structure may stand not as a bizarre and formless mass of facts, but as a new symphony in the realm of all nature's beauties.

"Prof. Niels Bohr, whom The Franklin Institute honors to-day with its highest award, may yet be counted a young man, but it was thirteen years ago that he laid the foundations of those ideas in atomic structure which have formed the bases of practically all our speculations since.

"Niels Bohr was born at Copenhagen in 1885. He comes of a scientific family, his father being a student of natural science, and his brother a mathematician of high repute. He received his education at the University of Copenhagen, where he was awarded the degree of doctor in 1911. His thesis on 'A Study of the Electron Theory of Metals' is a masterly treatment of the subject. It would doubtless be better known were it not eclipsed by his more epoch-making investigations in the realm of atomic structure. It was printed in Danish and was not therefore accessible to a large number of physicists, with the result that much of Bohr's work in this field was duplicated by others. Bohr felt quite keenly the difficulties he encountered in making this

work known. I happen to possess a copy of the thesis which I received from him at this time. It is full of pen and ink notations in English, made in the endeavor to convey to the reader an idea of the essential elements of the discussion in those parts where he suspected that the language would be an obstacle.

" In 1912 Bohr went to England, and after spending a short time at Cambridge he went to work with Sir Ernest Rutherford at Manchester, where he was subsequently appointed Reader in Mathematical Physics. His first paper while at Manchester dealt with the ' Decrease of Velocity of Moving Electrified Particles in Passing through Matter,' a subject which continued to occupy part of his interest for two or three years; but, in July, 1913, there appeared in the *Philosophical Magazine* the first of the papers which were to place him among the pioneers of science, a paper entitled ' The Constitution of Atoms and Molecules.'

" Up to this time nearly all efforts to understand spectra had been founded upon attempts to realize for the atom some mechanism which by its vibrations would continually emit the light we saw. Unfortunately, almost everything we knew about spectra rebelled against any sort of explanation along these lines. There seemed to be no way of accounting for the large number of frequencies obtainable from a simple element like hydrogen. Moreover, the relation between the frequencies of the lines in a series was of a kind foreign to almost any explanation in harmony with classical physics. These difficulties reflected themselves in attempts to find a suitable basic plan of structure for the atom. One phenomenon seemed to call for one style of architecture while another demanded, just as insistently, a different style. Finally, Sir Ernest Rutherford brought forth such weighty evidence in favor of the atomic picture as a planetary system with all the positive electricity concentrated in a central heavy nucleus around which the electrons revolved that reason demanded that this view be accepted and that such additional assumptions as were necessary to account for the optical facts be built around it as the basic structure. It was around this model that Bohr built his theory.

" Theoretical physics grows by the choice of suitable assumptions. A genius is one who in terms of assumptions, few in number and simple in kind, is able to correlate many facts; the master stroke made by Bohr consisted in his laying hold of the

Niels Bohr

few and vital assumptions which were necessary for the correlation of the spectroscopic data. He saw that the outstanding phenomena of spectroscopy called for the belief that the atom could exist in different states and that we must picture radiation not as something which is going on all the time, but as a phenomenon which occurs only during the transition from one state to another. On the basis of simple postulates following this idea, he gave a beautiful explanation of the famous Balmer formula for the spectrum of hydrogen. Moreover, his theory enabled him to calculate correctly within limits of experimental error, and from the fundamental constants of molecular physics, the fundamental constant of spectroscopy. He was also able to predict, successfully, as subsequent experiment showed, new spectral series and new lines in series already known. He was able to predict the form of the spectrum of ionized helium, and identify it with a certain spectrum which had been known for a long time but had always been associated with hydrogen. The spectroscopic constant for helium should be, according to his theory, very nearly four times that for hydrogen, and his predictions were in accord with the facts even to the extent of the slight departure from the exact factor, four.

"The beginnings made by Bohr were rapidly seized upon and developed by a host of investigators in physics and his work was further enriched and enhanced by these labors which served to emphasize at every stage the correctness of his fundamental concepts.

"In 1916 Niels Bohr was appointed Professor of Physics at his old university, the University of Copenhagen, and, in 1920, he was appointed Director of the Institute of Theoretical Physics, in which capacity he has drawn to himself a group of students from all parts of the world.

"Upon one who brings into being an epoch-making departure in modern physics much responsibility weighs. The world watches his every step, and expects him to take the foremost part in nurturing the newly born babe to maturity. Bohr has shown himself eminently fitted for the task. His first efforts were rapidly followed by another great stroke of generalization, his Correspondence Principle, in which he took a great stride towards harmonizing the older classical theory with the newer results of the quantum theory. Then followed a very careful survey of

the spectra of the elements with a view to extracting from them as far as possible the details of the atomic structure. His efforts in this direction have placed in our hands a picture of the atom which has been ever fruitful in stimulating further investigation and in correlating the facts of experiment.

" Bohr is a tireless worker who lives for weeks in his laboratory without emerging therefrom. None is harder worked yet none is more accessible to his students and to all who would seek his advice. He is eager to seize upon every new fact which points in some way to the solution of the great problem. An unbiased seeker after the truth, he has never shown himself irrevocably wedded to any favored idea, and has been the first to welcome and see the merit in the advances made by his co-workers in the field of atomic structure.

" Niels Bohr has been honored by many societies and institutions. He is a foreign member of the National Academy of Science, of the Royal Society of London, of the Göttingen Academy of Science and many other scientific societies. He has been honored with degrees from many universities, including those of Cambridge, Manchester and Edinburgh. He has been a recipient of the Hughes Medal of the Royal Society, the Barnard Medal of Columbia University, and of the Nobel Prize for Physics. In 1923 he visited this country to deliver the Silliman lectures at Yale University, and during this period he lectured at many other institutions and made many friends.

" It is a source of regret to us all that Professor Bohr cannot be with us to-day to receive the Medal of The Franklin Institute in person. We are, however, fortunate and highly honored in having with us the chief representative of the Danish Government, and I have, Sir, the honor and pleasure of presenting to you His Excellency, the Minister of Denmark, who on behalf of his Danish Majesty's Government will accept the Medal and Certificate for Professor Bohr and see that they are transmitted to him."

Doctor Eglin, in presenting the Medal and Certificate to His Excellency, Constantin Brun, said: " Your Excellency, The Franklin Institute of the State of Pennsylvania, through its Committee on Science and the Arts, has awarded to Prof. Niels Bohr the highest award in the gift of the Institute—the Franklin Medal

—for his distinguished work on the dynamic atom. It gives me great pleasure to present to you this Medal and a Certificate of Honorary Membership in the Institute, to which, upon recommendation of the Board of Managers, Professor Bohr has been duly elected."

The Minister in accepting the Medal and Certificate on behalf of Professor Bohr, graciously replied: "It is a great privilege for me that I have been asked to accept the Franklin Gold Medal on behalf of our Prof. Niels Bohr, and it has afforded me genuine pleasure to come here and receive the Medal in the presence of such a distinguished assembly. Professor Bohr has cabled to me asking me to express to you his great regret at not being able to be here in person, and his deep appreciation of the rare honor which you have conferred upon him. He knows, of course, the glorious history of your Institute and that the Franklin Gold Medal is coveted all over the world by the most distinguished scientific men. If he were here himself, I am sure that he would assure you that his endeavour in the future would be to make himself still worthier of the Medal, and he might perhaps add that he doubted whether he had yet made himself fully deserving of such an honor. But it is not for me to speak in that sense of him. I trust to your judgment of Professor Bohr, and it is with pride that I have learned of it, pride on behalf of Denmark. Nothing could more serve to promote cordial international relations than the recognition by the scientists of one country of the merits of the scientific men of another country, without trace of national jealousy.

"This Medal, I am sure, will be a great encouragement for Professor Bohr to continue his work with the benefit of the entire world as his aim and without fail double his admiration and affection for the American people.

"Permit me also, as the representative here of the Danish Government, to add their warm thanks and deep appreciation of the distinction granted to a Dane."

Doctor Eglin stated that, in the absence of Professor Bohr, which was sincerely regretted by all, a letter from him would be read by Professor Compton, of Princeton University. A second letter, regarding his inability to prepare a paper, was also read.

Regarding the conferring of the Medal upon him, Professor Bohr wrote:

"I thank you for your letter with the information that The Franklin Institute has awarded me the Franklin Medal.

"This great honor from an institution which associates its efforts with the memory of the immortal genius who stands as an ideal, not only to scientists, but to everybody interested in the progress of human civilization, has been a source of very great pleasure to me. I am very thankful indeed for this evidence of sympathy with my modest efforts in taking part in the exploration of the new domain of science, opened up by the discoveries regarding the structural units of the atom to which your countrymen have contributed so much.

"It should of course have been a very great pleasure and honor to me if I had been able to follow the invitation to be present at the meeting of The Franklin Institute on May twelfth and personally receive the medal. However, I regret that my duties and arrangements here make it impossible for me to come to America this spring. Still I hope that it will not last too long before I get opportunity to visit your country again and to meet with fellow scientists and friends.

"Asking you to extend my heartiest thanks and kindest regards to the president and council of The Franklin Institute, I am,

"Very sincerely yours,

"NIELS BOHR."

Regarding his inability to prepare a paper, Professor Bohr wrote:

"On receipt of your kind letter of April fifth I realized even more fully than before how unfortunate it is that I have been prevented to accept the invitation of The Franklin Institute to be present at the meeting of May twelfth and personally to receive The Franklin Medal. When writing my letter of March eighth, in which I tried to give expression to my feelings of thankfulness for the great honor your Institute has shown me, I had no knowledge of the custom that the recipient of the medal, at the occasion of the award, presents an address on some subject connected with his researches. When receiving your last letter I planned of course immediately the preparation of such an address, but it is with utmost regret that I must inform you that the circumstances have not allowed me to carry out this plan. Indeed, my health has not been satisfactory in the last months and has practically prevented me to overcome more work than claimed by my immediate duties.

"You will understand how much I regret this situation, and that it is only in this very last moment that I have abandoned the hope to comply with the customs of your Institute.

"In asking you to extend my apology to the president and council of your Institute.

"I am yours very truly,

"NIELS BOHR."

Award of the Franklin Medal and *Certificate of Honorary Membership.*

To Samuel Rea, Sc.D., LL.D., Former President, Pennsylvania Railroad.

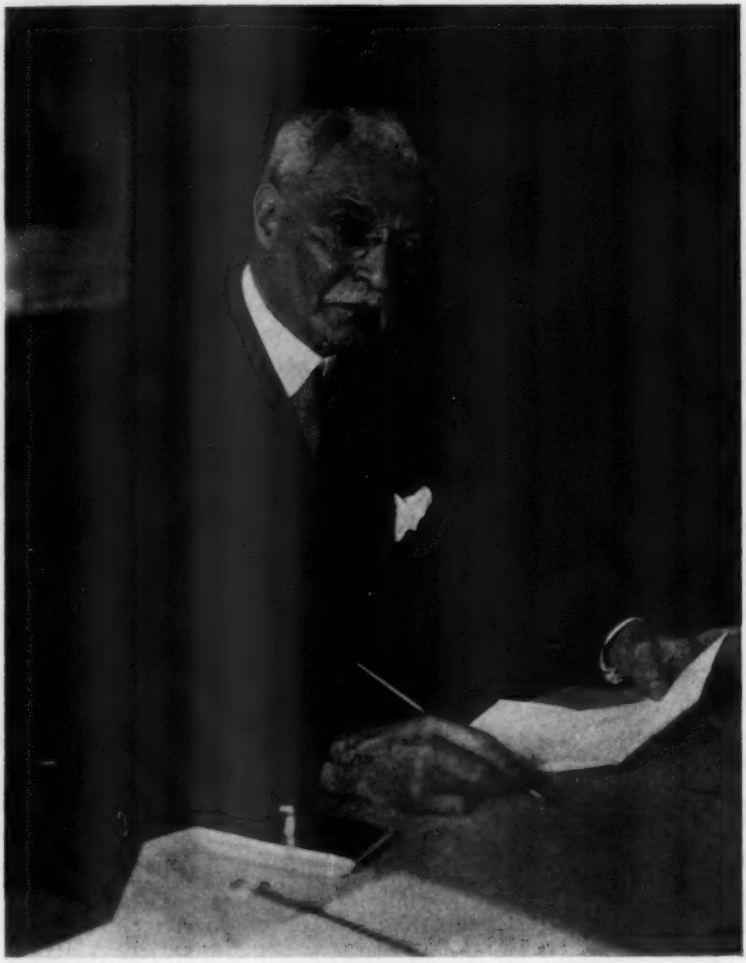
Dr. Walton Clark, former President of The Franklin Institute, introduced Doctor Rea. Because of the state of his health at the time, Doctor Clark requested Mr. Marshall Morgan, a member of the Board of Managers, to read his remarks. They are as follows:

"Mr. President: This year, for the first time, the Franklin Medal, the highest honor in the gift of the Institute, is awarded to a resident of Pennsylvania. Its receipt will add Doctor Rea to a notable group, and notably will he adorn it.

"During the ten years since its foundation, the Franklin Medal has been awarded in recognition of the most notable work of scientists of France, England, Holland, Belgium, Italy and America. Frequently it has been awarded for work in pure science. It is gratifying that the first Pennsylvanian to receive this medal has earned the title to it in a field in which the application of science to industry—the immediate application of useful discovery and invention to the betterment of man's condition—is an outstanding feature.

"To-day's medalist, Doctor Rea, began what was to prove a most distinguished professional career at the early age of sixteen years as chainman and rodman in the employment of the Pennsylvania Railroad. From the first, as he gained experience, he was advanced to positions of greater and greater responsibility, and this so rapidly that before he had arrived at his majority he had become assistant engineer of the Pennsylvania Railroad. With these advances to positions of greater importance came the opportunity to the young man to demonstrate his ability and industry and to win the regard and loyalty of associates and subordinates, thus paving the way to positions of greater and greater responsibility and usefulness. For fifty-five years he has watched and shared in the development of the greatest transportation system in the world, rising during that time from a position of relatively small importance to the position of highest responsibility in the railroad world.

"Since the beginning of his connection with railroad work fifty-five years ago, Doctor Rea's career has been coincident with



SAMUEL REA

a mechanical development in the transportation industry, the greatness of which may best be expressed by comparisons. In 1871 when young Rea joined the forces of the Pennsylvania Railroad, the tractive power of a locomotive was approximately 13,000 pounds. To-day it is 90,000 pounds. The carrying capacity of a box car at that time was approximately 12 tons. Now it is 50 tons. The wooden passenger coaches of that day have passed, and passengers of this day are carried in steel cars, almost infinitely stronger to resist the strain of derailment or collision than the cars in which the young Rea rode. Wooden bridges have given place to steel, and steel to stone. Better signal systems have been devised. Rail shapes and their weight and chemical composition have been greatly changed—all with vastly increased celerity, economy and safety of rail transportation. In the development of these and of the multitude of their natural and more or less important adjuncts our medalist had a part, growing in importance as he grew in experience, until we find him in responsible charge of the design and construction of one of the greatest, perhaps the greatest of all engineering undertakings of this generation, the New York tunnel extension and station. The success of this great work was due to Doctor Rea's long study of the problems involved. President James McRea, speaking of this work, said: 'If the project proves to be a failure, Mr. Rea must take the responsibility; if it is a success, he is entitled to the credit.' That it was eminently successful from an engineering point of view is known to railroad men the world over.

"Another of Doctor Rea's more notable accomplishments is the New York Connecting Railroad and Hell Gate Bridge, connecting the Pennsylvania Railroad with the New Haven System and through it to Montreal, Canada, and the Long Island Railroad—a stupendous undertaking—planned and constructed under Doctor Rea's direction.

"These few of Doctor Rea's many engineering accomplishments, evidence of his almost unexampled skill in the application of science to industry, alone place upon The Franklin Institute an obligation to do him honor.

"But it is not to be understood that these great works, accomplished coincidently with bearing a leading part in the management of a great railroad, were possible to a man whose knowledge of human affairs has only to do with their engineering side. To

satisfactorily render an essential service to millions of people in thousands of communities scattered over a score or more states, and coincidently to win the loyalty and affection of hundreds of thousands of subordinate employees, requires a knowledge of human nature as well as a knowledge of materials—a kindliness of spirit as well as a keenness of intellect. It is the knowledge that Doctor Rea possesses these characteristics as well as great engineering ability that contributes most to our pleasure in awarding to him our highest honor—the Franklin Medal and Diploma.

" Mr. President, closing this utterly inadequate appreciation of Dr. Samuel Rea's high character and notable accomplishments, and pursuant to the recommendation of the Committee on Science and the Arts, I present Doctor Rea to receive the Franklin Medal at your hands."

Acknowledging the presentation of Doctor Rea and conferring the Medal upon him, Doctor Eglin said:

" Dr. Samuel Rea: We of the Institute are glad to have you presented by Dr. Walton Clark, President of the Institute for seventeen years, to receive the Franklin Medal, which, by virtue of the authority conferred upon me, I have the honor to present to you in recognition of your outstanding work in the conception and construction of railroads, terminals, tunnels, and bridges, and of your eminently successful applications of the principles of science, economics, and human relations to railroad engineering and administration, in which you have displayed vision, imagination, and courage of a high order.

" It is also my pleasure to advise you that upon the recommendation of the Board of Managers and unanimous vote of the Institute, you have been elected an Honorary Member of the Institute, certificate of which I now hand you.

" This is also of especial interest to the members of the Institute, as one of the founders of the Institute in 1824, Samuel Vaughan Merrick, was the first president of the Pennsylvania Railroad, from which office you have recently retired."

A paper prepared by Doctor Rea for this meeting, entitled " Engineering Reminiscences," was then delivered by him. (See page 165.)

Doctor Eglin expressed the warm thanks and congratulations of the Institute to Doctor Rea upon the interesting and informative character of his paper, and then declared the meeting adjourned.

Copper-cadmium Wire. N. F. BUDGEN. (*Electrician*, April 30, 1926.)—The metal cadmium has acquired a new importance from the valuable properties of its alloys with copper, tin and zinc, but it is likely that its chief application in the future will be as a constituent to a small degree in drawn copper wire. Smith in 1921 found that copper wire containing a little cadmium was scarcely reduced in electrical conductivity, while it possessed a high tensile strength and resistance to abrasion. The conductivity comes down less than 1 per cent. for each .1 per cent. of cadmium added to the copper. The tensile strength increases slowly with added cadmium until the latter amounts to .6 per cent. The addition of more cadmium causes a rapid increase in the tensile strength. Copper wire with 1.1 per cent. cadmium can be subjected to a temperature of 260° for thirty minutes and afterwards show scarcely any sign of softening—a marked contrast to the effect produced on pure copper by the same heat treatment. A copper-cadmium wire with 20 per cent. greater tensile strength than a wire of pure copper can be bent seven times to a right angle and back before it breaks, whereas the wire of pure copper breaks after four such bends. In a torsion test the compound wire showed itself four times as good as the pure one. In a test of trolley wire under working conditions the loss in diameter during eight months was less than one-third as much for copper-cadmium wire as for copper wire.

On account of its properties above given copper-cadmium wire has approved itself for technical uses in both hemispheres.

G. F. S.

Alkaline Polysulphides.—CARL Z. DRAVES and HERMAN V. TARTAR, of the University of Washington (*Jour. Am. Chem. Soc.*, 1926, **48**, 1527–1529), have studied the reaction which occurs when metallic sodium or potassium is added to an excess of sulphur dissolved in boiling toluene in an atmosphere of hydrogen. The sulphides which form are insoluble in toluene. They were collected, and subjected to quantitative analysis. Sodium yielded its trisulphide, Na_2S_3, while potassium yielded its pentasulphide, K_2S_5.

J. S. H.

A New Steel for Small Houses. (*Popular Science Monthly*, July, 1926, p. 55.)—A light structural steel which can be used for small houses in much the same manner in which heavier beams are employed in skyscrapers has been perfected recently by a Pittsburgh manufacturer. The new steel, while light in weight, has greater proportional strength than any other steel so far produced. Hitherto lightweight steel was impossible because there was no known way of rolling it, but after many years the necessary rolling process has now been perfected. The new steel can be used for floors and roofs as well as for beams.

R.

FORMAL PRESENTATION OF THE INSULL PORTRAIT TO THE FRANKLIN INSTITUTE.

In 1914 Dr. Samuel Insull, President, The Commonwealth Edison Company of Chicago, presented to The Franklin Institute a fund sufficient to establish and maintain the Franklin Medal, the highest award of the Institute. His interest in The Franklin Institute has continued unabated. In recognition of his outstanding contributions to the development of the public utilities industries, as well as of his helpful interest in science, as evidenced by the funding of the Franklin Medal, twenty-seven intimate friends and business associates of Doctor Insull caused a special portrait to be painted by Mr. Leopold Seyffert, of Philadelphia and Chicago, for presentation to the Institute. This portrait was formally presented in the Hall of the Institute at four P.M. on Friday, May twenty-first. The order of exercises was as follows:

PROGRAMME.

Meeting in the Hall of the Institute ..... 4 P.M.

"Samuel Insull, a Many-sided Man" ..... B. E. Sunny

The Franklin Medal—Its Significance.. Howard McClenahan
Secretary, The Franklin Institute

Formal Presentation and Unveiling of the Portrait,
Louis A. Ferguson

Acceptance of the Portrait ..... Wm. C. L. Eglin
President, The Franklin Institute

Address ..... Samuel Insull

The meeting was called to order by the President, who immediately presented Mr. B. E. Sunny, Chairman of the Board of Directors, Illinois Bell Telephone Company of Chicago. Mr. Sunny spoke as follows of:

SAMUEL INSULL, A MANY-SIDED MAN.

"In reviewing the record of Samuel Insull, one must inevitably come to the conclusion that in planning a career, the most important thing for a young man to do is to select a hero! Mr. Insull did it, when he was twenty-one, and became the Private Secretary

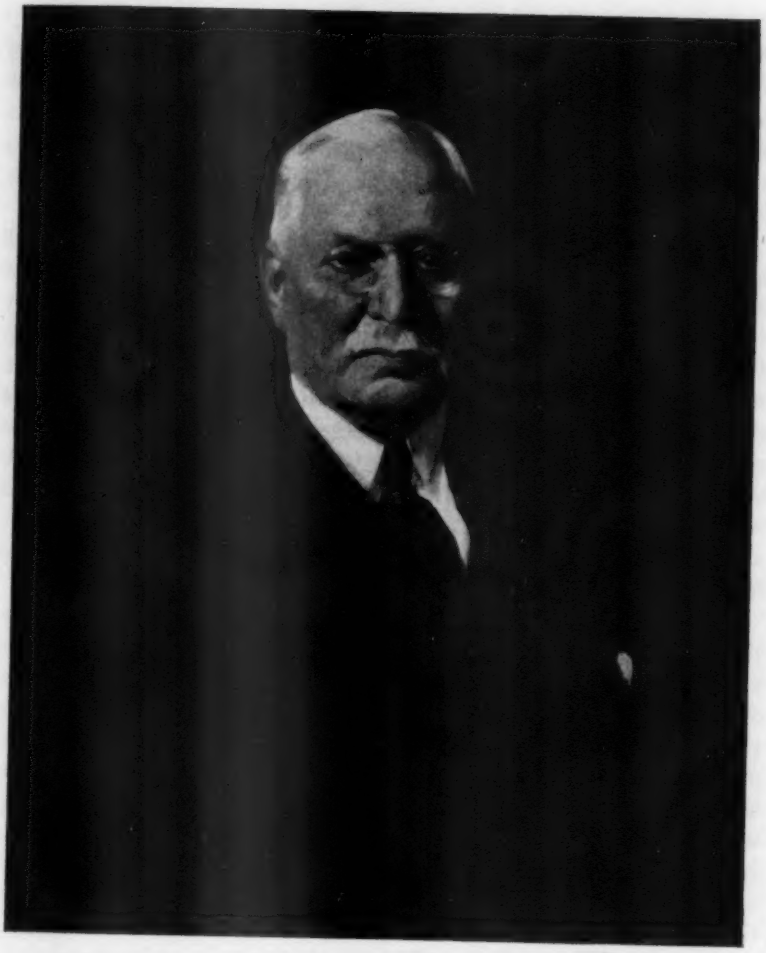
and enthusiastic admirer of Thomas A. Edison. Then the young man must stick to his hero and never let him get away from him. Mr. Insull did this, too. In forty-five years the electrical world has looked on, and approved and enjoyed, one of the finest examples of devoted friendship between two men since Damon and Pythias. Insull says of Edison, 'I think in no part of this world, to which the efforts of modern industrialism have pushed themselves, will you find a country where the name of Edison is not a household word.' And Edison says of Insull, 'He is one of the greatest business men in the world, and as tireless as the tides.' They have been saying inspiring and beautiful things of the sort about each other all these years, and have been of tremendous mutual help. We saw the potence of Edison's influence when Samuel Insull came to Chicago in 1892, after an association of twelve years with Edison, to take the Presidency of the Chicago Edison Company. This was one of several small central station companies then in operation; about four years old; with a capitalization of $883,000, paid in with considerable misgiving; and operated with small units in a very limited territory. The possibilities of the business were but scantily recognized, and there was neither courage nor money to go ahead except in piecemeal and timid fashion.

"Mr. Insull brought with him an up-to-the-minute, intimate and accurate knowledge of the central station business, and a vision and confidence in its future, in so fine a field as Chicago offered that enabled him to become an energetic and loyal interpreter and demonstrator of Mr. Edison's ideas and methods.

"He immediately and aggressively made his plans for extensions and additions, the prospective cost of which made the conservative directors gasp.

"The Adams Street Station was outgrown, and the first task was to build the Harrison Street Station, now in its turn but a memory. It was begun in 1892 and put in operation in 1894, and had a total capacity of 16,200 kilowatts in various sizes of direct connected units, among them two of 800 kilowatts each, the largest built up to that time, from the World's Fair exhibit of the General Electric Company which, as Vice-president of the Edison General Electric Company, Mr. Insull had helped plan.

"In this station were begun the first experiments in Edison central stations, in alternating current generation with alternating



SAMUEL INSULL

current transmission to distant substations, where the energy was changed into direct current for local consumption.

" Load factor was a cardinal feature in Mr. Edison's original central station plan, in that he relied on a motor load to keep the plant in efficient operation during the hours of small lighting load. Mr. Insull's campaign for improved load factor began when the increased facilities of this station afforded the opportunity, and has been vigorously continuous throughout. He was the first to adopt the Wright Demand Meter and establish differential rates in the United States.

" In studying the load factor of his own company, Mr. Insull became necessarily a student of diversity factor, as exemplified by the electrical requirements of the whole community. Early in his studies he saw that it would be better for all concerned, if the light-and-power, railway and all other electrical requirements of the city, were supplied from one central source. He developed the theory of the advantage of massing the production of electrical energy, and persuaded the elevated and surface railway companies to buy all their power from his company, which was no easy task, in view of the fact that the street-railway operators of that day were hard-headed utility men themselves, and had first-class modern plants of their own.

" The first railway power contract became effective in 1902, the purchaser being the Lake Street Elevated Railroad. Within a comparatively short time contracts were entered into with all the elevated and surface street-railway companies of the city. More recently the Illinois Central Railroad contracted to purchase its energy for the electrified suburban service, from two central station companies under Mr. Insull's direction, the Commonwealth Edison Company and the Public Service Company of Northern Illinois.

" To his wisdom and courage in securing large railway contracts at wholesale rates, the success of the Commonwealth Edison Company is largely due, and his example was an inspiration to electricity-supply administrators the whole country over.

" Mr. Insull applied himself diligently to the task of securing a city-wide organization and, despite much difficulty and opposition, acquired ownership of one large competitor and scores of small and comparatively uneconomical central stations in the two hundred square miles of area of the present City of Chicago.

"The urgent requirement was now on to lower manufacturing costs for electric current, especially to secure the large power business in sight. This led to the consideration of larger units, and the subject of steam turbines *versus* reciprocating engines became a live issue in 1901 and 1902, when the new generating station at Fisk Street was being planned.

"The largest turbine that had been built up to that time was but 500 kilowatts, while reciprocating engines ten times larger were obtainable.

"When the engineers, after many months of study here and abroad, finally submitted their findings to Mr. Insull, it was without recommendation with respect to the steam turbine. The risk involved in a change so radical was evidently beyond their courage.

"Mr. Insull, however, took the responsibility upon himself, which he has been in the habit of doing when the situation required it, and contracted for three 5000-kilowatt turbo-generators, the first of which went into operation in October, 1903. It was successful, as we all know, and almost immediately took its place as one of the most important contributions to the economical manufacture of electricity.

"The significance of the experiment will be better realized when it is explained that, at that time, the largest reciprocating engine unit was 5000 kilowatts, weighing 1,777,000 pounds, and operated at 75 revolutions per minute. The turbine unit weighed 540,000 pounds, or about one-third, and operated at 500 revolutions. The foundation required for the engine weighed 4,300,000, and for the turbine 630,000 pounds. The floor space for the engine, 1600, and for the turbine 280 square feet, respectively, while the cost of the turbine was about 40 per cent. less than that of the engine.

"Because of the great bulk and weight, it does not seem possible that the size of the reciprocating engine or its efficiency could ever be increased in an important way, while, on the other hand, as it quickly developed, the 5000-kilowatt was but the beginning for the turbine, and the 7500-kilowatt size came along in a few months, then constantly larger sizes, with increased efficiency at every step.

"The Commonwealth Edison Company is now operating a 60,000-kilowatt in the Crawford Avenue Station; has an 88,000-

kilowatt on order, and is planning for a 200,000-kilowatt in a new station to be located near Chicago.

" An interesting fact in connection with the installation of the first three 5000-kilowatt machines was that the Edison Company had sold the output in advance, and that the General Electric Company had taken orders for turbines having a total rated capacity of 240,000 kilowatts, depending on the successful operation of the pioneer units.

" The value of the incandescent lamp; three-wire system; steam turbine, and other inventions is of course beyond calculation, but it is nevertheless true that the aggregate of the value of the practices and methods, which have made these inventions so universally applicable to our industrial and domestic needs, is even greater, and to Mr. Insull's initiative, energy and enterprise, we are immeasurably indebted for these results.

" In testimony of his leadership in administrative skill, the two national organizations, the National Electric Light Association and the American Street Railway Association, in the eager competition of some of the ablest managed companies for service supremacy, awarded the Charles A. Coffin Medal to the Public Service Company of Northern Illinois for 1923; the Chicago and North Shore and Milwaukee Railroad Company for 1924 and the Commonwealth Edison Company for 1925—all Insull companies!

" The award to the Commonwealth Edison Company was made Wednesday evening last, at a crowded session of the National Electric Light Association, by President James E. Davidson to Mr. Insull, standing on the platform by the side of his old friend and mentor, Thomas A. Edison, whose glowing face expressed his gratification of the honor paid to his associate. The awards were for 'distinguished contribution to the development of' electric light and power, and electric transportation, 'for the convenience of the public and the benefit of the industry.'

" Among the great strides in electrical development in thirty-five years, I shall mention a few!

" In 1892, the Chicago Edison capacity amounted to 3500 kilowatts, and at the end of this year it will be 960,000 kilowatts.

" The usual boiler pressure at that time was 100 pounds, and is now, in places, approaching 1200 pounds.

" It took twelve pounds of coal to produce a kilowatt hour in

1892. This can now be done with one and one-half pounds of coal.

"It used to require three and one-half watts of energy per candle-power, while now it takes a little over one watt, and the average life of the incandescent lamp is double.

"The load factor in Chicago has risen from 22 per cent. in 1897 to 47.4 per cent. in 1925.

"In 1903 the effective output was equal to about 9 per cent. of the heat energy of coal consumed, and it is now 25 per cent.

"In 1892 it was a serious problem to transmit 2500 volts through underground cables. Arrangements are now being made for underground transmission in Chicago at 132,000 volts.

"The average residence rate in 1892 was 19.5 cents per kilowatt hour, and is now reduced to 5½ cents.

"The capital of the Edison Company in 1892 was $883,000. It is now $187,500,000.

"When Mr. Insull cleared Chicago of competing companies, he turned his attention to the territory outside of the city where he acquired many properties now constituting the very successful Public Service Company of Northern Illinois, of which he is Chairman.

"In 1912 he organized the Middle West Utilities Company, the largest in his group, operating in nineteen states from Maine to Texas. He is Chairman of this Company, and is also Chairman of the Chicago Rapid Transit Company, owning and operating the elevated railways in Chicago. He is likewise Chairman of the Chicago and North Shore Electric Railway, operating an exceedingly successful interurban which, by reason of the excellency of its service, has taken from two first-class steam railways the bulk of their traffic between Chicago and Milwaukee.

"Mr. Insull's success in electricity has recently been repeated by him in sensational fashion with respect to gas.

"In 1913 he became Chairman of the Board of the People's Gas Light and Coke Company, an old established utility which for years had been harassed and annoyed by controversies with the municipalities. In the war, its difficulties increased greatly by reason of fixed rates, while the cost of gasoil and labor increased two- and three-fold. The payment of dividends was continued at reduced rates until 1917, at which time Mr. Insull

was devoting his entire time to the duties of the Chairmanship of the State Council of Defense.

"In 1919 the affairs of the Company became so critical that it was on the point of defaulting its bond interest. Mr. Insull took the Presidency of the Company, arranged for funds to meet the bond interest; contracted for a new gas manufacturing plant to be built by a separate company; infused a new spirit into the discouraged and disorganized personnel; ironed out the relations with the public, the press, and the 700,000 customers. His efforts were so successful that in two years the Company was practically out of its difficulties, resumed dividends first at the rate of 5 per cent., which was gradually increased until 1925, when the old rate of 8 per cent. was reëstablished.

"This is one of the most inspiring records of public utility rehabilitation that we have had, and is a great tribute to Mr. Insull's adaptability, resourcefulness and administrative skill. That he has established a reputation for himself as a gas manufacturer is proven by the fact that a man with large experience in that line, when asked, 'Who is there in the gas business who ranks in importance with Samuel Insull in the electric business?' replied promptly 'Samuel Insull!'

"Mr. Insull's international reputation as a financier is well deserved. The Commonwealth Edison Company has a forty-year record of dividend payments, and the Public Service, Middle West, Gas, and other companies under his control, have equally good records for shorter periods. The interests of the security holders have been scrupulously guarded under all circumstances. A purchaser of many hundreds of lighting properties, he has never approved a hard bargain, but preferred that the seller be always satisfied that he had been liberally dealt with. A careful and exacting negotiator of large and complicated contracts in vast sums, where differences have arisen, not involving the good faith of the contractor, he has frequently volunteered adjustments of great fairness and generosity. During the stress of war his personal fortune was pledged without hesitation to protect one of the largest of public utilities in the group in his control.

"If his fortune even approached his success as a creator and operator of utilities, he would be as rich as Crœsus, but money making for himself has never to any of us seemed to interest

him nearly so much as making two blades of grass grow where one grew before.

"Such information as leaks out respecting his philanthropies is consistent with and adds emphasis to his record of generous and universal helpfulness.

"Mr. Insull has been a civic helper and burden bearer for many years and, among his many accomplishments, it is not too much to say that he saved Grand Opera for Chicago.

"For some years Mr. and Mrs. Harold F. McCormick had been the mainstays of opera in Chicago in the way of making up the annual deficit. The discrepancy between receipts and expenditures had amounted to considerably more than a million dollars a year. It was announced well in advance that the 1921–1922 season would be the last in which they would undertake to carry this burden. The other guarantors did not feel like assuming a burden of such proportions.

"An organization formed and sponsored by the Association of Commerce to make opera a truly civic enterprise undertook to raise a guaranty fund of $500,000 a year for five years. It succeeded in getting pledges amounting to approximately $225,000 a year, and seemed unable to get any further.

"Mr. Insull was appealed to, and under his direction a guaranty fund of something more than $500,000 a year for five years was pledged during the early part of 1922. The business affairs of the opera and its management were completely reorganized. The Chicago Civic Opera Company was organized a little later with Mr. Insull as President, and he has continued to supervise and direct its affairs.

"He undertook this out of sincere belief that opera is a real civic asset, one that is necessary to round out a city's claim to metropolitan stature. He works at it in response to his creed that 'Every man owes it to the community in which he makes his living, to do something for the community that he doesn't get paid for.'

"Under Mr. Insull's guidance the annual deficit, which the guarantors have been called upon to make good, has been usually well below $400,000 a year. The total cost of an opera season averages little, if any, more than the annual deficit used to be, but it is generally agreed that the quality of opera provided for Chicago has never been better.

"He is now supervising the signing of pledges for another guaranty fund of $500,000 a year for five years, and is encouraging the opera lovers of Chicago to look forward to having the opera established on a sound and permanent basis with a home of its own.

"The war record of this distinguished citizen is a notable one. The fact that he was born in England might be regarded as an embarrassment, and no doubt would have been to some men but it was not to him. In 1916, when we were not yet in the war, he said, 'We owe a great deal to this country. We owe everything to it except birth, and what we all love so much, that liberty, which was given us by that Mother Country from which we spring. But we owe our opportunities in life to this Country. We do not want to be British-Americans here, nor English-Americans, nor Irish-Americans, nor Scotch-Americans. We want to be Americans.'

"When the United States finally espoused the cause of the Allies in 1917, Mr. Insull dropped everything not absolutely requiring his attention, and gave his great abilities entirely to war work in Illinois, where help was so urgently needed.

"Governor Frank O. Lowden appointed Mr. Insull Chairman of the State Council of Defense, and that highly patriotic, untiring body, under his leadership, accomplished a great task. It organized the public mind of the state for every war need; and in men, money and materials, in unselfish response to every call for service, Illinois did itself proud. Many devoted men and women took part in achieving this result but, under the Governor, Mr. Insull was the leader in civilian war work in the state, and his splendid record of patriotic achievement will stand for all time.

"At the close of the war when the soldiers came back with banners flying—and no jobs, he said—'Put them on the pay-roll first and find jobs for them afterward.'

"'If you ever expect to succeed,' he has told his employees on another occasion, 'you must carry out the idea that the other fellow is entitled to a chance.'

"Mr. Insull is the foremost publicist in the electrical business, and his energetic and continuous educational campaign has been inspiriting and stimulating to inventors and engineers, as well as to builders and operators of utilities.

"His addresses on many platforms, here and abroad, to every type of audience have been informative of every step forward in the central station business, and a generous contribution to the public service of the world, of the results secured through vast expenditures of time, effort and money, by himself and his companies.

"These addresses, privately printed, are in two large volumes entitled 'Central Station Electric Services,' and 'Public Utilities in Modern Life.'

"His educational interest and activity is not limited to the utility field. Many of his addresses have been to college and university gatherings on other topics, and to his own employees, to whom he is a very cordial friend and sympathetic adviser.

"As is well known here of course, he founded the Franklin Medal—'To those Workers in Physical Science or Technology, without regard to Country, whose efforts have in the judgment of the Institute done most to advance the knowledge of Physical Science or its application.'

"He recently carried through successful negotiations with the Northwestern University, by which it will take over Armour Institute of Technology, which has grown in importance and expenditure beyond the means of its former sponsors. In this transaction Mr. Insull assumes responsibility for raising a very large sum of money.

"His public services have been recognized and greatly appreciated in educational circles. Union College conferred on him the Honorary Degree, 'Doctor of Science,' as 'Pioneer in Public Utility Development and a Leader in Civic and Industrial Progress,' while Northwestern University has conferred upon him the Honorary Degree, 'Doctor of Laws,' in a citation as follows: 'Pioneer in Public Utility Development; President and moving spirit of the Chicago Civic Opera Company; Trustee of St. Luke's Hospital, and active worker in its behalf; Chairman of the Illinois State Council of Defense; Patron of Music; humanitarian and public-spirited citizen; a leader in civic and industrial progress.'

"Mr. Insull as a farmer is again a pioneer in the age-old industry of agriculture, especially in the fundamental economics of farming.

" His first farm purchase was of 273 acres near Libertyville, Ill., made in May, 1907. Additions have been made from time to time until he now has 4256 acres.

" This acreage is operated as a combination grain and stock farm. He keeps a herd of pure-bred Brown Swiss cattle in the dairy, and breeds a few Suffolk Punch horses with which he wins blue ribbons at the annual International Live Stock Exposition in Chicago. But the chief industry on the farm is the raising of grain and the feeding of beef cattle, hogs and sheep for the market.

" Mr. Insull's farm is conducted as a business, and not as a pastime. ' Above everything else,' he has said, ' I am interested in working out the farming proposition on commercial lines, just as you would work out any other problem of production.'

" It is operated with as close attention to cost accounting, to labor-saving methods, and to economic procedure as could be applied in any other commercial or industrial business.

" In other words, he is applying the same principles to farming that he has applied in the various phases of the central station electrical business, and with a similar purpose in mind, namely, to get at the fundamental economics of the business.

" While I must finish, the half has not been told! I realized at the outset, the meagre opportunity to speak of Mr. Insull's many-sidedness in the time that could be taken on this occasion, and that there was much that must be left out. All who are familiar with Mr. Insull's activities will readily notice the omissions and I trust will pardon them. After all, this is not a biography, but a passing salute to our much admired friend.

" And now reverting to the opening paragraph, if the young man shall select Samuel Insull as his hero, and I warmly commend the choice, I need scarcely say that his career will be one of constant and continuing toil; of sacrifice of leisure and comfort; of burdens and responsibilities; of contest and controversy; of force and sternness; of tenderness and charity. His patience must never tire nor his courage weaken.

" But he will succeed! And his neighbors will gather about him and give him their trust and affection and call him Great."

The President presented Dr. Howard McClenahan, Secretary of The Franklin Institute, who spoke of

THE FRANKLIN MEDAL—ITS SIGNIFICANCE.

" Mr. President, Doctor Insull, Members and Friends of The Franklin Institute: To award a medal seems to be a continuing impulse of the human spirit. From the earliest days of the beginning of civilization, down to the present time, the award of medals, the striking of coins, to celebrate a noteworthy deed or event, seems to have been a primitive instinct among all men. The Egyptians, the Greeks, the Romans, have left us many such tokens of distinction. Now, to-day, we have medals which are awarded for valor in combat, for courage and sacrifice, for exploration, for literary or musical or artistic productions, for medical or surgical attainment, for success in politics, in government, in philanthropy, or for scientific discovery or development. Their name is legion, but they all have one feature in common—they all connote excellence and accomplishment.

" Our interest, of course, is chiefly in medals which are awarded for some reason of a scientific nature, and especially for excellence in the physical and mathematical sciences. There are many such medals which are presented for widely varying reasons. Some are awarded for particular excellence along very narrow lines; others are awarded for one particular and significant deed or invention or discovery; others are awarded on the basis of a lifetime of successful devotion, discovery and development in a general field.

" We cannot enumerate anything like all of the medals which are in existence. We can but name a few typical ones:

" The Faraday Medal is awarded for notable scientific or industrial achievement in electrical engineering.

" The Kelvin Gold Medal is awarded triennially for invention, to a large extent.

" The Bessemer Medal is awarded for important or remarkable invention in connection with the manufacture of iron or steel.

" The Victoria Medal was instituted in honor of her late Majesty, Queen Victoria, to be awarded for conspicuous merit for research in geography.

" There are astonomical medals, meteorological medals, chemical medals, and many medals for work done in biology. These are but a few of the foreign medals.

" In the United States there are the—

" John Fritz Medal, awarded for noted scientific or industrial achievement;

" The Edison Medal, for meritorious achievement in electrical science or electrical engineering;

" The Willard Gibbs Medal, for conspicuous research in pure or applied chemistry;

" The Ericsson Medal, awarded to an American of Swedish origin, or to a Swede, in recognition of accomplishments in science and engineering;

" The Perkin Medal, founded in commemoration of the fiftieth anniversary of the coal-tar industry, and awarded to a chemist for valuable work in applied chemistry;

" The Coffin Medal, awarded for the greatest contribution toward increasing the advantages of the use of the electric light and power for the convenience and well-being of the industry;

" The Theodore M. Vail Medal, awarded for the purpose of stimulating among telephone employees the highest spirit of public service;

" The Magellanic Medal, awarded annually by the American Philosophical Society, to the author of the best discovery or the most useful invention.

" Scores of other medals might be mentioned. The citation of the above will suffice to show the variety in the conditions of award.

" The Franklin Institute was founded for the promotion and dissemination of a knowledge of the mechanic arts. From the outset, it has sought the recognition of inventions and the reward of inventors. Through its Committee on Science and the Arts, it has for more than a century passed upon the value of inventions and, as its means permitted, has granted recognition to inventors. With its various medals of varying significance, it rewards individual invention, or new developments of old inventions, or discoveries in science, or lives of successful devotion and discovery in scientific pursuits. It awards medals for discovery in the limited field of railway engineering, and gas engineering, and medals for literary quality in articles of intrinsic merit appearing in the JOURNAL of the Institute, as well as medals for work along more general lines in the physical sciences. Our several medals—the Longstreth, the Wetherill, the Potts, the Henderson, the Elliott Cresson, and the Franklin Medal, form a series of medals

of ascending order of merit which are awarded for attainments of increasingly high order.

"Up to 1914, the highest medal of The Franklin Institute was the Elliott Cresson Gold Medal. In that year Dr. Samuel Insull generously donated the fund for the support of the Franklin Medal and thereby made it possible for The Franklin Institute to establish its highest award—the Franklin Medal. This Medal is the symbol of the highest honor which can be awarded to any scientist by this institution. Its award is limited only in the sense that it is presented for brilliant success in the physical sciences. It is not limited to any branch of any science, but may be awarded for work in physics or chemistry or engineering or astronomy. It is not awarded for any individual invention, nor usually for any single discovery. It is awarded 'to those whose efforts have contributed most to a knowledge of physical science and its applications.' It is rather to be regarded as the recognition which is granted for work of the highest character carried on successfully through many years. It offers, therefore, the recognition for a life of brilliantly successful devotion to physical or mathematical science. It is to be ranked with only a few medals—such as the Medal of the Royal Society of England; the Copley Medal founded in 1736, awarded for the most important scientific discovery; it has few equals and no superiors in the field of scientific recognition. Its establishment and the award of it have given an additional and marked reason for the standing of The Franklin Institute in the nation. The award of the Franklin Medal is an honor which is sought for and cherished the world over.

"To you, Sir, whose generosity has made it possible for us to add to our series of medals this highest honor of all, we express our continuing gratitude and appreciation."

Mr. Louis A. Ferguson, Vice-president of the Commonwealth Edison Company of Chicago, was next introduced. He made the following

PRESENTATION ADDRESS.

"Mr. President and Members of The Franklin Institute: To the Public Utility men of this country a portrait of Samuel Insull seems particularly appropriate in the halls of The Franklin Institute.

"In this twentieth century he has shown so much of the Franklin spirit! His many-sided leadership in widely diverse

fields; his international prominence in the world of finance; his instinctive application of sound economic principles; his far projected vision of the marvellous development of democratic institutions, and his intimate concern with the betterment of individual life in this favored land, seem to us a close parallel to the most significant qualities of your most distinguished patron.

"The group of businesses to which Mr. Insull has given his life is the most important outcome of the electrical development originated by Benjamin Franklin.

"This fortunate union of the man and the industry is certainly worthy of lasting commemoration.

"Mr. Insull has been my chief during thirty-four years of my professional service, and it gives me a particularly keen, personal pleasure to represent the donors of this portrait, each of whom is a leader in the industry of Franklin.

"Only those of us who have been most closely associated with him, appreciate the *full* breadth of his capacities; the *full* range of his genius, and we who know him best take the deepest satisfaction in giving him our respect and confidence.

"It is in this spirit of whole-hearted appreciation that we tender to The Franklin Institute this portrait of one of the greatest generals in the field of American public service, this leader of men, Samuel Insull."

At the conclusion of his talk, Mr. Ferguson unveiled the portrait, which had previously been hung in the Hall of the Institute.

The President of the Institute accepted the portrait in the following terms:

> "Mr. Ferguson: The Franklin Institute appreciates the gift of Dr. Samuel Insull's portrait by his friends.
>
> "All of Doctor Insull's life work typifies the aims and ideals of this historic institution, and particularly the life of one of its founders, Samuel Vaughan Merrick, who first became an important manufacturer of machinery, was instrumental in the introduction of gas into the City of Philadelphia, and was the first president of the Pennsylvania Railroad, one of the great utilities of this country.
>
> "We are greatly honored to hang this portrait in

our Hall with the other illustrious men who have been so helpful in the affairs of the Institute."

The President then presented Dr. Samuel Insull, who made the following brief acknowledgment of this tribute to him:

"The opportunity to participate in the foundation of the Franklin Medal was to me a great privilege. Its presentation was a matter of little or no consequence financially, but one of great possibilities to workers in connection with research and applied science. The distinguished standing which the Medal has reached is owing to the very great wisdom of the trustees of this Institute, exercised through its Committee, in deciding who should be honored from year to year by its presentation. It is a very remarkable thing that within a relatively few years of its establishment, it should have become practically the 'blue ribbon' coveted by all who enter research or the application of the sciences. The list of distinguished men who have been honored by its receipt, including not only men prominent in research and discovery, but also those prominent in connection with the application of the sciences, is a very great credit to this institution, and I hope that in the years to come the influence of the Medal will be so great that it will add additional lustre to the fame of The Franklin Institute, the existence of which has meant so much to the material and educational development of this great city.

"I appreciate very much the way I have been received here to-day, and the remarks which Mr. Sunny and Mr. Ferguson have made. I can only say that nine-tenths of it is not deserved by me."

The meeting then adjourned to the Library, where Doctor Insull was greeted by the members of the Institute and their friends.

Fluid Resistance to Moving Spheres. R. G. LUNNON. (*Proc. Royal Soc.*, A754.)—Spheres were allowed to fall through distances ranging from 1.12 m. to 538 m., in college buildings, chimney-stack and coal mine. In one mine draughts from side galleries joined to other disadvantages caused the rejection of the observations made after the installation of three-fourths mile of wire. The times were ordinarily obtained from the automatic record of a chronograph,

but there were instances when this was impossible. Then a stop-watch was used.

Extensive tables of observations are given that bring out in strong relief the difference between the fall of bodies in a vacuum and in air. A series of steel balls with diameters ranging from .317 to 1.83 cm. fell through distances increasing from 3.37 to 538.5 m. Of course the observed time of the fall increased in every instance with the distance fallen. In addition the time spent in falling through a given distance increased as the diameter of the falling sphere grew less or, to state the same fact in another way, the retardation of the instant of actual arrival at the bottom after the instant when the sphere would have arrived had it fallen in a vacuum grew larger both with the distance fallen and with reduction in the diameter of the falling ball. For 3.37 m. of fall the larger sphere mentioned above had a retardation of .002 sec., while the smaller had .011 sec. For 538.5 m. the retardations were, respectively, 2.39 and 11.55 sec., the small ball taking more than twice as long to fall as it would have taken in a vacuum.

The larger steel spheres were still gaining speed after falling 320 m., but from the data observed in other cases the terminal speeds, the constant speeds finally attained in falling, were calculated. For a rubber ball 10.2 cm. in diameter with a mass of 32.3 g. the terminal velocity was 13.6 m. per sec.; for another rubber ball of diameter 3.75 cm. and mass 13 g. it was 23.5 m. per sec.; for a steel sphere, diameter .873 cm., mass 2.69 g., it was 42.3 m. per sec.

A series of experiments was made by dropping through five different distances ten steel balls, .476 cm. in diameter, which were alternately clean and rusty. For every distance the rusty balls took less time to fall than the clean ones. The difference was only one or two-thousandths second, but it existed. The wake left in the air has probably something to do with this anomaly. G. F. S.

The Influence of Temperature upon the Reflection of X-rays by Calcite. E. NIES. (*Ann. d. Phys.*, No. 8, 1926.)—In 1914 Debye announced his conclusions that, when X-rays simulate reflection from the surface by reason of their diffraction by the atoms of a crystal, the heat motion of the atoms must weaken more and more the intensity of the reflected rays as the temperature rises. The intensity should be further diminished by a reduction of the atomic weight of the participating atoms by a reduction of the forces holding them in place and by the use of orders of spectra higher than the first. Bragg and others have already confirmed by experiment these theoretical predictions. The present investigation undertakes to examine the effect upon reflection of the reduction of the temperature of a calcite crystal from 20° C. to the temperature of liquid air—190° C. The examination was made with Cu-Kα radiation in the first order spectrum. The lowering of temperature by 210 degrees was found to cause an increase of about 2 per cent. in the reflecting power of the crystal. G. F. S.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

A COMPARISON OF X-RAY AND WHITE-LIGHT EXPOSURES IN PHOTOGRAPHIC SENSITOMETRY.[1]

By R. B. Wilsey and H. A. Pritchard.

THE characteristic curve of a photographic material for X-ray exposures was found similar in form to that for white light; as a rule the X-ray curves showed a longer toe, sharper shoulder, and a higher gamma than the white-light curves. Both types of exposure gave a similar convergence of the straight-line portions of the characteristic curves developed for various times. X-rays and white light gave the same maximum density on the same material, this density corresponding to the total mass of silver per unit area of the original emulsion. In the region of normal exposures, the rate of development was found to increase with exposure, this effect being generally greater for X-rays than for white light, the highest development rate reached with X-rays was usually greater than that for white light. Reversal due to overexposure (solarization) was found to consist of a decrease in rate of development, the reversal effect disappearing on complete development.

The differences in the forms of the X-ray and white-light characteristic curves, and the differences in the progress of development of the various exposures, could not be explained by the differences in the penetration of the radiation in the emulsion layer, but must be due largely to differences in the character of the latent image.

THE RELATION BETWEEN DIFFUSE AND SPECULAR DENSITY.[2]

By C. Tuttle.

PHOTOGRAPHIC images, produced by exposure and development of photographic materials, consist of minute particles of metallic silver embedded in a matrix of transparent gelatin.

* Communicated by the Director.

[1] Communication No. 257 for the Research Laboratories of the Eastman Kodak Company, and published in *J. Opt. Soc. Amer.*, 11, June, 1926, p. 661.

[2] Communication No. 258 from the Research Laboratories of the Eastman Kodak Company and published in *J. Opt. Soc. Amer.*, 11, June, 1926, p. 559.

Such a deposit is a semi-diffusing medium of which the effective transmission is dependent upon the characteristics of the optical system of which it is a part. If such deposits are used for the making of contact prints, all of the transmitted radiation becomes effective, while if they are used in an optical system which projects images by means of lenses or mirrors, such as in projection printers, motion picture machines, stereopticons, etc., only the specularly transmitted component is utilized. The relation between values of specular and diffuse density is therefore of considerable interest from the practical as well as the theoretical standpoint.

Diffuse and specular density measurements were made on three photographic materials. Two densitometers, one of the integrating sphere type and the second of the projection type, were used. The data obtained are shown to fit an equation of the exponential type. The ratio of light scattered to the total transmitted light is a linear function of transmission for high transmission values.

SENSITIZATION BY NUCLEI OF SILVER SULPHIDE.[1]

By S. E. Sheppard.

THIS article consists of a reply to the comments of P. E. Henri on the author's theory of sensitization by nuclei of silver halides in the process of emulsification. It is pointed out that the auxiliary hypothesis of disorientation of the crystal lattice of the silver bromide by inclusion of silver sulphide specks is not regarded as necessarily altering the energy of light required to make a grain developable, but only the distribution of this photochemical energy. It is further shown that this disorientation must on modern views involve a deformation of the ions composing the silver bromide lattice in such a manner that the deformation increases centripetally toward the silver sulphide nucleus.

It is now suggested in the present paper that beside the specific rôle of the silver sulphide nuclei acting as concentration specks for development, they may play an active rôle in exposure by re-radiation of absorbed light energy to increase the lattice disorientation of the silver halide around them and thus facilitate the

[1] Communication No. 259 from the Research Laboratories of the Eastman Kodak Company and published in *Brit. J. Phot.*, **73**: 33, 1926.

formation of photochemically reduced silver upon them. It is also pointed out that the hypothesis of ionic deformation should involve a second order optical sensitizing effect, by inclusion of substances like silver iodide and silver sulphide in the crystal lattice and that some evidence for this has been obtained in this Laboratory.

INVESTIGATIONS ON PHOTOGRAPHIC DEVELOPERS. III. THE EFFECT OF DESENSITIZERS IN DEVELOPMENT.[4]

By M. L. Dundon and J. I. Crabtree.

A DESENSITIZER is used primarily to secure greater visibility during development, although it also prevents aerial oxidation fog. Greater visibility may also be obtained by so choosing a safelight that the visual intensity of the light which it transmits is a maximum and its photographic intensity in relation to the emulsion used is a minimum.

A practical desensitizer in addition to having a satisfactory desensitizing action must not affect the latent image or the shape of the characteristic curve of the developed image. It must also not give fog or stain and should be soluble and stable in a developer. No desensitizer is known which is stable in a developer rich in hydroquinone.

The properties of the following commercial desensitizers have been studied in the light of the above requirements: Phenosafranine, pinakryptol green, pinakryptol yellow, basic scarlet *N*, and aurantia.

The limits of safety in the use of pinakryptol green with motion picture negative and panchromatic emulsions have been determined. This desensitizer was chosen because it appeared to be the most satisfactory of the known desensitizers at the time of this investigation.

The comparative safety of untreated film and film desensitized for varying times with varying concentrations of pinakryptol green to different safelights has been studied. By bathing panchromatic film in a 10^{-4} solution of pinakryptol green, or after it has been in a developer containing 1/25,000 of this desensitizer for two or three minutes, inspection of the film may be conducted

[4] Communication No. 270 from the Research Laboratories of the Eastman Kodak Company and published in *Amer. Phot.*, **20**: 378 *et seq.*, 1926.

with safety with a Series 4 Wratten safelight containing a 25-watt bulb at a distance of one foot. Under the same conditions motion picture negative film may be safely examined with a Series o safelight.

A latent image on a desensitized emulsion tends to bleach out when exposed to red light. This bleaching action is greatest with non-color sensitive emulsions. With panchromatic emulsions the effect is not serious and after development has commenced no appreciable bleaching occurs. With desensitized non-color sensitive emulsions the safe time of exposure to a red safelight is determined by the time required to destroy the latent image and not by the time required to produce fog.

Data have been obtained on the fogging action of various desensitizers with developers.

An exhaustive study has also been made on the effect of pinakryptol green when used in the developer instead of as a preliminary bath.

THE TERNARY SYSTEM: SILVER BROMIDE—POTASSIUM BROMIDE—WATER.[5]

By Raymond H. Lambert.

THE solubility of silver bromide in saturated potassium bromide solution has been determined at temperatures between 30° and 100° C. As much as 10 per cent. by weight of silver bromide is dissolved at 100° C. From these data and those obtained from the literature on the corresponding binary systems, it is possible to develop the entire surface between solid and liquid phases describing equilibrium. It has also been shown, the same can be done for the corresponding chlorides. In the case of sodium and lithium halides, however, no eutectic mixture of the salts exists and therefore no definite solubility can be established.

In compound formation, such as with the corresponding iodides, the ternary system becomes very complex so that much more data would be necessary. An X-ray study of various mixtures of silver bromide and potassium bromide gives strong evidence of no compound formation between silver and potassium bromides in the solid state.

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[5] Communication No. 273 from the Research Laboratories of the Eastman Kodak Company and published in *J. Phys. Chem.*, **30**: 972, 1926.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

CRYSTALLOGRAPHY OF COMPOUNDS OF CARBON.[1]

By G. L. Keenan and R. M. Hann.

[ABSTRACT.]

THE optical properties of a large number of carbon compounds have been compiled. Formulæ are arranged in order of increasing carbon atoms and the following data are noted in adjoining columns: Crystal system, class optic sign, observed optic axial angle, true optic axial angle, and orientation. Each compound is followed by a reference to the original literature. This material is included in volume one of the *International Critical Constants Tables.*

CAN CORROSION AND BLACKENING IN CERTAIN MARINE PRODUCTS.[2]

By D. B. Dill and P. B. Clark.

[ABSTRACT.]

AN investigation, extending over six years, has been made of some of the deteriorative changes which may occur in sterile marine products. Neither free oxygen nor volatile bases appear to be significant factors in can corrosion or in the blackening of the flesh. The content of sulphide sulphur is related to the blackening process. The sulphide-sulphur content of those marine products which do not blacken is small and does not increase during storage. The sulphide-sulphur content of crustacea, which do blacken, increases to relatively high values during storage. Those products which corrode cans are more alkaline than pH 6.5. Marine products more acid than pH 6.5 never blacken and for the most part do not corrode the container.

* Communicated by the Chief of the Bureau.

[1] Published in Vol. I of the *International Critical Constants Tables.*

[2] Published in *Ind. and Eng. Chem.*, **18**, No. 6, June, 1926.

SCYLLITOL FROM FLOWERING DOGWOOD (CORNUS FLORIDA).[3]

By Raymond M. Hann and Charles E. Sando.

[ABSTRACT.]

SCYLLITOL, $C_6H_6(OH)_6$, was first isolated by Staedeler and Frerichs from the kidneys and other organs of certain plagiostomous fishes. It has since been found in acorns, in the leaves of *Cocos plumosa* and *Cocus nucifera,* and in the leaves of *Helinus ovatus.*

This isomer of inositol has now been isolated from the flowers and bracts of flowering dogwood (*Cornus florida*). It was identified by the combustion of the purified substance and of its hexacetyl derivative and also by means of its crystallographic and optical properties.

A NEW FACTOR FOR CONVERTING THE PERCENTAGE OF NITROGEN IN WHEAT INTO THAT OF PROTEIN.[4]

By D. Breese Jones.

[ABSTRACT.]

IN THE light of results recently obtained from a study of the proteins of wheat bran, a new factor for the conversion of the percentage of nitrogen in wheat into terms of protein has been calculated. The conversion factors for the nitrogen in the three parts of the kernel are: Bran, 6.31; endosperm, 5.70; embryo, 5.80. By basing the calculation on the percentages of nitrogen in the individual proteins of the endosperm, embryo, and bran, and on the relative proportions in which these proteins are present, the conversion factor 5.83 is obtained for the nitrogen of the whole kernel, instead of 5.7, the factor generally used.

Use of Fluosilicates in Agriculture.—S. MARCOVITCH, of the Tennessee Agricultural Experiment Station (*Ind. Eng. Chem.*, 1926, **18**, 572–573), describes the use of fluosilicates (silicofluorides) in agriculture. Sodium fluosilicate and calcium fluosilicate are of value as insecticides, while the former salt also has value as a fungicide and bactericide in the control of certain diseases of plants. J. S. H.

[3] Published in *Jour. Biol. Chem.*, **68**, No. 2, May, 1926.

[4] Published in *Cereal Chem.*, **3**, No. 3, May, 1926.

NOTES FROM THE U. S. BUREAU OF MINES.*

THE SIZING ACTION OF A COAL-WASHING TABLE.

By Byron M. Bird.

THE prevailing practice of washing unsized coal, ½-inch and finer, to ⅛-inch and finer, on a table is subject to certain limitations which are commonly overlooked. In some instances good results are obtained by this method, but often the opposite is true and the efficiency of the washing operation is low. Experimental data were obtained in the course of coal-washing investigations conducted by the U. S. Bureau of Mines at the Northwest Experiment Station in coöperation with the University of Washington and with certain coal operators of that state.

The general method of study has been to take a large number of zonal products from the table, and separate them according to specific gravity and size into their component parts. The table used is one of the standard commercial sizes with a diagonal deck. The coal to be washed is split into representative portions, which are stored in separate bins. One portion is used for "tuning up" the table; the products are collected continuously in the same sludge tank and returned to the feed bin, and thus a closed circuit is completed. When the desired conditions on the table are obtained, coal is fed from one of the reserve bins. After the table is operating smoothly the entire product is caught for one minute; such a sample is sufficiently large to represent accurately the work of the table and at the same time to minimize the effect of variations. Beginning at the end next to the head motion, separate samples are made for each foot along the edge of the deck.

Each zonal sample is separated by the float-and-sink test, into four products, by the use of three solutions of definite specific gravities. The specific-gravity fractions resulting from the float-and-sink separations are sized with Tyler screens, and the moisture and ash content of each size determined. The final distribution of particles, according to size and to specific gravity, effected by the table is portrayed by this procedure.

* Communicated by the Director.

The coal-washing table separates according to size and to specific gravity. The distribution according to size will either aid or impede the specific-gravity separation, depending on the relative size of particles of coal and impurities. A grouping of particles such as results from hindered-settling classification makes it possible to utilize this sizing action in making a separation of bone from coal; this grouping is particularly of advantage when the differences in specific gravity are small. Further details are given in Serial 2755.

EXPLOSIBILITY OF OIL-SHALE DUST.

By Vernon C. Allison and Arthur D. Bauer.

THE explosibility of coal dust has long been recognized by competent investigators as constituting one of the dangers of mining coal and in the use of pulverized coal as a fuel in industrial plants. The Bureau of Mines has carried on extensive series of experiments dealing with this subject, and has not only developed methods for the practical prevention of this danger, but in the course of these experiments has developed a standard method of determining the relative explosibility of coal dusts and other organic dusts.

Oil shale contains compounds of carbon and hydrogen that are either of a petroleum nature and are strongly absorbed upon the incombustible part of the shale, or else are present in the shale as a compound ("kerogen") which has the property of changing into petroleum-like products when acted upon by heat. The oil shales may contain varying amounts of the organic matter, ranging from a trace to more than 66 per cent., depending upon their richness; therefore, it is important to know whether the dusts formed in mining and handling these oil shales are explosive when mixed with air and if so, to indicate remedial measures. Explosibility tests were made of several pulverized oil shales, selected as being typical of those which in the future may be used in commercial shale-oil production.

Few of the problems of mining oil shale have as yet been encountered and solved in the United States, because no commercial production of shale oil has been attempted. Mining methods will depend largely on local conditions and on the physical characteristics of the deposits, but it is probable that underground

methods similar to those used in coal mining will be used. In the eastern states where the black oil shales of a cannel-coal nature overlie coal seams near the surface, and elsewhere where conditions permit, stripping or quarrying methods may be feasible.

The dust produced in Scottish shale-mining operations, according to some investigators, is non-inflammable and non-explosive. However, this must not be taken to indicate that oil shale of similar characteristics will be encountered in American shale mines. The results of the present tests show that oil-shale dust may present a source of danger in American mines, particularly when comparatively rich material is being worked. Further details are shown in Serial 2758 of the Bureau of Mines.

MAGNETIC CONCENTRATION OF FLUE DUST OF THE BIRMINGHAM DISTRICT.

By Oscar Lee, B. W. Gandrud, and F. D. DeVaney.

Losses of iron ore through the production of flue dust vary between wide limits in different furnaces, and depend on a number of factors, such as size and design of furnace, amount of fines in the ore, the operating conditions and the blast pressure. Blast-furnace operators of the Birmingham district keenly realize this waste. The ores are comparatively low grade and require more fuel than is ordinarily used elsewhere. Hence the flue dust is low in iron content and high in coke. As a result it is not in suitable condition for direct sintering. In many other iron and steel centres direct sintering is a common practice.

The operators of the district are endeavoring to prevent this waste, and at their request the Southern Experiment Station conducted an investigation of methods of recovering flue dust.

The charge and the operating conditions at the various furnaces from which samples were obtained are so variable that no single sample of flue dust can be taken as representative. Likewise samples from the same furnace varied greatly in physical characteristics and in chemical composition. Hence a successful concentration process must be capable of operating under a varying feed.

The coke can readily be removed by gravity concentration, for example, hydraulic classification. However, after the coke has been removed the remaining low-grade iron ore is not amenable

to satisfactory concentration by ordinary methods. This is due primarily to intimate interlocking which requires grinding to 100 mesh to liberate the hematite from the gangue. Material of such fineness is difficult to handle by gravity concentration.

In a number of the samples hot reducing gases in the blast furnace or in the dust catcher had converted the iron minerals from hematite or limonite into magnetite. When such an alteration had taken place, a good separation of the iron mineral from the gangue can be obtained by use of magnetic concentration machines.

Magnetic concentrators of various kinds, such as a magnetic wet cobber, a magnetic dry concentrator, and a magnetic log washer, were used on flue dust in which the iron mineral had been converted into magnetite. The first two machines are built to handle coarse material, and the log washer is designed to handle fine material. The results obtained with these different machines show that a good concentrate and a high recovery can be made by the dry concentration or the wet cobber without preliminary crushing. It is doubtful whether the added expense of fine grinding would be justified by the higher grade of concentrate obtainable in the magnetic log washer. Additional information is contained in Bureau of Mines Serial 2761 recently issued.

The Application of Radiography to the Study of Capillarity. E. A. OWEN and A. F. DUFTON. (*Proc. Phys. Soc. London,* April 15, 1926.)—Copper tubes well amalgamated within and thoroughly cleaned were held in a vertical position with their lower ends dipping into distilled mercury. The liquid rose in the metal tubes as water rises in glass capillary tubes. By an X-ray tube a metre distant a radiograph of each tube was taken upon a plate or film close behind it. Thus a permanent record was secured from the measurement of which the surface tension of mercury was calculated. At 17° C. this was 485 dynes/cm. The same method was applied to photographing the rectangular hyperbola formed by mercury rising between two vertical plates of copper in contact along a single vertical line and making a small angle with each other. Radiographs were obtained of the depression of mercury in three small steel tubes.

In the discussion that followed the paper a speaker stated that a manufacturing firm had proposed to him the problem of reading the height of the mercury in a piezometer tube of steel surrounded by a water jacket, the walls of the tube being 4 mm. thick and the bore 8 mm. He got a sharp image of the mercury meniscus by using an X-ray tube with its focus 45 in. from the mercury. An exposure of 10 secs. was given. G. F. S.

THE FRANKLIN INSTITUTE.

LIBRARY NOTES.

RECENT ADDITIONS.

DAWIDOWSKY, F.—Die Leim- und Gelatine-Fabrikation. Third revised edition. 1893.

ETTELE, CLAUDE.—Lubricating Oil Salesman's Primer. 1926.

FERRIER, R.—Les Nouveaux Axiomes de l'Électronique. 1925.

GIBBS, W. E.—The Dust Hazard in Industry. 1925.

HAAS, ARTHUR.—Introduction to Theoretical Physics. Two volumes. 1925-1926.

HIRSCH, MEIER.—Sammlung von Beispielen, Formeln und Aufgaben aus der Buchstabenrechnung und Algebra. 1816.

KOLLER, THEODOR.—Praktische Herstellung von Lösungen. 1888.

KRIES, FRIEDRICH.—Lehrbuch der reinen Mathematik. 1822.

MACH, ERNST.—The Principles of Physical Optics. 1925.

MEADE, RICHARD K.—Portland Cement: Its Composition, Raw Materials, Manufacture, Testing and Analysis. Third edition. 1926.

MINGLE, J. G.—Draft and Capacity of Chimneys. 1925.

National Electric Light Association.—Relay Handbook. 1926.

NOYES, W. A.—Organic Chemistry for the Laboratory. Fifth edition, revised. 1926.

PARSONS, WM. BARCLAY.—Robert Fulton and the Submarine. 1922.

ROGERS, ALLEN, Editor.—Elements of Industrial Chemistry. Second edition. 1926.

BOOK REVIEWS.

BELT CONVEYERS AND BELT ELEVATORS. By Frederic V. Hetzel, M.E., Member of the American Society of Mechanical Engineers, Member of The Franklin Institute of Pennsylvania. Second edition, revised, xi–333 pages, 9 × 6 inches, cloth. New York, John Wiley and Sons, Inc., 1926. Price, $5 net.

The first edition of this treatise was surveyed in these pages shortly after its appearance in 1922. A few additions, only, have been found desirable. Notable among these are improvements in the design of belt-conveyor idlers with anti-friction bearings, a most important detail upon which, the author states, much of the future progress of belt conveying will depend. Several new forms of elevator buckets which have been adopted within the last three years are also described and their probable influence on high belt speeds for grain elevators are pointed out.

The work is of particular interest to engineers who must have quantitative information and an analytic *rationale* of the subject. These the reader will find in ample measure clarified by the generous number of 288 well-executed line-cuts and half-tones distributed throughout the text. About two-thirds of

the book is occupied by the first section, Belt Conveyors, by which material is transported in contact with a belt which is operated in general at no great declivity. The remainder deals with Belt Elevators in which the gradient of the belt, to which buckets are attached, more nearly approaches or attains the vertical.

Chapter I contains a general description of the component parts of belt conveyors. With this is an illuminating set of ten annotated diagrammatic cuts of typical belt-drives and arrangement of loading chutes and trippers. A brief but satisfactory account of early history and development are given in Chapter II. The manufacture of rubber belts, their structure and a multiplicity of other items in the technique of this basic component of the conveyor are considered at length in Chapter III. Supporting and guiding the belt, idlers and troughing the belt come next in Chapter IV. Chapter V, on driving the belt, gives the method of determining the horse-power required, and other related calculations with an example fully worked out. Tension and take-up devices, loading the belt, discharging from the belt, protecting and cleaning the belt are given adequate analysis in the next four chapters. The remaining chapters of Section I are respectively devoted to package conveyors, special uses for belt conveyors, life of belts and when to use belt conveyors. These are mere chapter headings, each of which includes a large number of separate topics of vital interest to the designer who would have a long search to find elsewhere the design data and analysis collected here. In this connection it may be mentioned, there are fifty-eight tables of design data, such as weights of specified kinds of conveyor belting, spacing of idlers, spacing of buckets, work of pick-up in elevator boots, etc.

The last ten chapters which constitute section II relate to belt elevators. The chapter headings are: General descriptions, centrifugal discharge elevators, elevator buckets, continuous bucket elevators, belts for elevators, fastening buckets to belts, driving belt elevators, elevator boots, inclined elevators and elevator casings. The matter of this section is treated in the same thorough detail as is accorded the first section. There is no formal bibliography but many references to original sources of information are cited in the text.

The author, whose qualifications are exceptional, has produced an authoritative and analytical work which will well earn the hearty appreciation of all those who are engaged in the rational design of belt conveyors and belt elevators. It is to be hoped that he will write a companion treatise on chain conveyors; the present work bespeaks for it a warm welcome. The quality of press-work is of high order. LUCIEN E. PICOLET.

PORTLAND CEMENT. By Richard K. Meade, M.S. xii–706 pages, 206 illustrations, 8vo. Easton, Penna., The Chemical Publishing Company, 1926. Price, $10.

The initiative of this work, the author tells us, was a small volume issued in 1902 on the "Chemical and Physical Examination of Portland Cement." This was succeeded by a larger volume with the present title and now there is published the much increased third edition. Originally intended for chemists and cement engineers the work described tests and analyses only. The section

on manufacture has increased with each edition and now constitutes the larger portion of the book. Much of the text has been re-written for this edition. The analytic methods and the methods of physical testing have been revised to accord with the present American standards. Some information as to foreign methods and specifications has been added.

Some interesting notes are given on the history of the uses of mortars and cements. The employment of lime mortar antedates written history as far as now known. It has been found in the ruins of a temple of high antiquity on the island of Cyprus. The Egyptians, however, used a material containing gypsum in the construction of the pyramids. The Romans discovered the setting qualities of a mixture of lime and volcanic ashes and used this for harbor and river work and for cisterns and conduits. From this use until the latter part of the eighteenth century no advance was made in the technology of building materials. The forward step was made by John Smeaton in meeting the problem of building the Eddystone lighthouse. He needed a mortar that would harden under water and after a series of experiments found that limestone containing some clayey matters made better lime for building purposes than the purer forms. Smeaton's discovery was developed by later workers. In 1824, Joseph Aspdin took out a patent for a material that he called "Portland cement" because when it hardened it resembled the stone taken from the quarries at Portland, England. The discovery of cement rock in 1818 in Madison County, N. Y., led to the establishment of the industry in this country and to the use of the material by Mr. C. White in the construction of the Erie canal, of which he was the engineer.

The cement industry has now become a very extensive one in all industrial nations, and has made a profound impression upon building operations. An interesting chapter is the account of the methods for settling the dust from kilns. The Cottrell electric process and a water-spray process have both been used. During the war when potash salts from Germany were unobtainable, a profit was realized from the potassium content of the dust, but this is now unavailable, though settling methods are still used to prevent nuisances. The author's long-established position in the field to which the book is devoted guarantees that it will be a comprehensive and trustworthy guide to both chemist and engineer.

HENRY LEFFMANN.

ORGANIC CHEMISTRY FOR THE LABORATORY. By W. A. Noyes, Ph.D., University of Illinois. Fifth edition, revised. xiii–329 pages, 45 illustrations, 8vo. Easton, Penna., The Chemical Publishing Company, 1926. Price, $4.

This is an excellent presentation of the present-day problems in organic chemistry as needed in laboratory work. A notable and commendable feature is the comparatively large scale on which some of the procedures are conducted. Thus the distillation of wood is carried out with 1200 grams of material. Inasmuch as the present edition is the fifth, there is little need to discuss the merits of the book; they have been amply shown by the reception that the student body has accorded to it. Many commendable features are exhibited. References, especially to the original literature, are abundant. The year is in

parenthesis as is now the custom in the literature of the American Chemical Society and has been adopted as a world standard. The reviewer is not wholly friendly to this plan, favoring the order series, year, volume, page. Thus *Ann. chim. phys.* [8], **4**, 319-488 (1905), would preferably appear as [8], 1905, **4**, 319, it being scarcely necessary to indicate the final page of the article. The matter is, however, of minor importance; the principal point is that authors shall give both volume and year when both are employed in the periodical and shall not use Roman numerals in any case. It is to be hoped also that publishers will discontinue the practice of designating some of the preliminary pages of books by such numerals. Books should begin with page 1, which should be the regular title page.

Doctor Noyes' book has demonstrated its value by use. In the present edition the references have been revised and several new fundamental analytical methods have been introduced. The spelling of the American Chemical Society has been adopted, as might be expected. This includes the use of "f" instead of "ph" in "sulphur" and all its derivative terms. There is, in truth, little orthographic or orthoëpic gain in this, and it is to be regretted that the Society retreated from its attitude of a couple of decades ago, when the final, useless, and even misleading, "e" was dropped from the names of the halogens, their derived terms and from the names of the alkaloids. English spelling is a disgrace to the nations that use the language, but a singular conservatism prevents reform. There is compensation in the fact that when Norman clerks bewitched our tongue they incidentally got rid of the distinctions of gender which are so absurd and confusing in most other forms of speech.

HENRY LEFFMANN.

LUBRICATING OIL SALESMAN'S PRIMER. By Claude Ettele, B.S. 111 pages, illustrations, 8vo. Easton, Penna., The Chemical Publishing Company, 1926. Price, $3.

The enormous development of machinery in factory operation, in transportation, and the introduction of mineral oils have added many problems in theory and practice of lubrication since the days of the simple application of axle-grease to the farmer's wagon. The volume in hand is a clear and comprehensive summary of the general principles of lubrication and of the nature, characters and applications of mineral lubricants. Incidental allusions are made to other forms, including the admixtures of graphite, talc and similar fine, smooth solids, but the use of these is deprecated, except for a few special purposes. A brief account is given of the chemistry of the hydrocarbons, but this is really a subject which cannot be presented satisfactorily to persons not trained in chemistry. A statement is made that carbon is the most abundant element, which must be understood as applying only to the substances treated in the book, as it is not true of substances at large. The book is liberally and clearly illustrated and the text generally well written. The "split infinitive," that awkward construction now so common in American books, is much in evidence here, "to immediately absorb" and "to periodically open" being examples noted.

In addition to the data concerning the nature of mineral oils, their testing

and the condition of use, much useful information is given concerning modern machinery and important types of industry such as refrigeration, power transmission, machinery, prime movers and driven machines. The book covers the field that lies between the petroleum chemist and the mechanical engineer, both of whom, as the author points out, know their special lines, but the oil salesman must be familiar with the practical use of oils and the principles involved therein. This book, to use the author's favorite form, "will properly present" the data.

HENRY LEFFMANN.

ELEMENTS OF INDUSTRIAL CHEMISTRY. By Allen Rogers. Second edition, x–680 pages, 135 illustrations, small 8vo. New York, D. Van Nostrand Company, 1926. Price, $4.50.

This is an abridgment of the well-known large treatise on the subject edited by Rogers and assisted by forty collaborators. The abridged issue has been prepared to meet the need of teachers who find that the time at their disposal for teaching the subject does not permit of the use of the larger work, moreover that work is hardly suitable for a students' manual, but can be part of the reference library of the department. Necessarily, being based on the comprehensive work, the abridgment will be entirely satisfactory as to the information, the only matter on which there can be a difference of opinion may be as to the character of the selection, on which point disagreement might occur but it will not be of serious moment. As the present edition is the second and as the first went through three printings, it is evident that the book has found favor and has filled a want. It contains a very considerable amount of material on applied chemistry which has now become so important and so extensive. Abundant illustration is given of machinery in actual use. Theoretical information necessarily plays a secondary part, but is given when helping the understanding and appreciation of the descriptions.

There is a regretful indifference throughout the book in regard to nomenclature, which is almost entirely that of the factory and not of the class-room. Such phrases as "chromate of lead," "acetate of lime" are out of place in a work primarily intended for students. The use of the final "e" when it does not render the preceding vowel long is a blemish on English spelling. It will be difficult to get rid of it in common writing, but scientists have their terminology largely under their control and effort should be made to eliminate such spellings as "glycerine," letting alone the fact that "glycerol" is the correct form. Indeed, an excessive tendency to the redundant "e" seems to mark the book, for vanillin and cumarin are so spelled. "Benzol" is in the index but not "benzene." The equals sign is used in all equations showing chemical changes. There seems to be prevalent a view that a book intended for teaching practical science need not be particular about form and phrase, but teachers should use the standard terminology and be exact as to literary form.

The book will place its users in possession of correct information on all the important industrial procedures of the present time.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report 236, Tests on Airplane Fuselages, Floats and Hulls. By Walter S. Diehl, Bureau of Aeronautics, Navy Department. 22 pages, illustrations, quarto. Washington, Government Printing Office, 1926. Price, fifteen cents.

This report is a compilation of test data on airplane fuselages, nacelles, airship cars, seaplane floats, and seaplane hulls, prepared by the Bureau of Aeronautics, at the request of the Committee. The discussion of the data includes the derivation of a scale correction curve to be used in obtaining the full-scale drag. Composite curves of drag and L/D for floats and hulls are also given.

Report 238, The Effect of Flight Path Inclination on Airplane Velocity. By Walter S. Diehl, Bureau of Aeronautics. 10 pages, illustrations, quarto. Washington, Government Printing Office, 1926. Price, five cents.

This report was prepared at the request of the Committee in order to supply a systematic study of the relations between the flight velocity V and its horizontal component V_H, in power glides. Curves of V and V_H plotted against the inclination of the flight path θ are given, together with curves which show the maximum values of V_H and the corresponding values of θ. Curves are also given showing the effect of small departures from the horizontal in high-speed performance testing.

PUBLICATIONS RECEIVED.

Portland Cement: Its Composition, Raw Materials, Manufacture, Testing and Analysis, by Richard K. Meade, M.S. Third edition. 707 pages, illustrations, 8vo. Easton, Penna., The Chemical Publishing Company, 1926. Price, $10.

Organic Chemistry for the Laboratory, by W. A. Noyes, Ph.D. Fifth edition, revised. 329 pages, illustrations, 8vo. Easton, Penna., The Chemical Publishing Company, 1926. Price, $4.

Lubricating Oil Salesman's Primer. An outline of the science of lubrication intended for the embryo salesman, by Claude Ettele, B.Sc. 118 pages, illustrations, 8vo. Easton, Penna., The Chemical Publishing Company, 1926. Price, $3.

Elements of Industrial Chemistry, by Allen Rogers. An abridgment of Manual of Industrial Chemistry written by forty eminent specialists and edited by Allen Rogers. Second edition. 680 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1926. Price, $4.50.

Belt Conveyors and Belt Elevators, by Frederic V. Hetzel, M.E. Second edition, revised. 333 pages, illustrations, 8vo. New York, John Wiley and Sons, Inc., 1926. Price, $5.

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The Determination of Surface Tension by the Method of Ripples. P. N. GHOSH, D. BANERJI, and S. K. DATTA. (*Phil. Mag.*, June, 1926.)—Lord Rayleigh worked out a stroboscopic method of getting surface tension from a study of the ripples set up by a blade attached to a tuning-fork. The authors seek to improve the method and at the same time to discover whether it gives as reliable values for surface tension as are furnished by other methods. They avoid the use of a second fork and thus escape the difficulty of making the two forks exactly synchronous. They photograph the wave form of the ripple and from this permanent record calculate the surface tension. The values they get are in agreement with those obtained by Weinstein and Volkmann, who employed the capillary tube method, but are lower than results got by others who used different methods. The new method gives for water at 18.5° C. the value 72.81 dynes/cm. for its surface tension and for the same liquid at 64.1°, 64.58 dynes/cm. G. F. S.

New Dye for Photographing Infra-red Rays. (*Popular Science Monthly*, July, 1926, p. 53.)—A new dye called "neocyanin," which may prove extremely valuable to astronomers in photographing the hitherto invisible infra-red rays, has been developed recently by a great American photographic concern. The ordinary photographic plate is sensitive only to blue light and the shorter invisible ultra-violet rays. It can, however, be sensitized to other colors by the use of dyes. The new dye makes them sensitive to light waves of 1/22,000 of an inch, while the longest rays visible to the naked eye are 1/30,000 of an inch.

Plates treated with the new dye may prove a great aid to spectroscopy, for the spectroscope shows light and dark lines in the invisible infra-red region of stars, which hitherto the astronomer was unable to distinguish clearly. R.

CURRENT TOPICS.

The Status of the Question of the Transmutation of the Chemical Elements. F. HABER. (*Naturwissenschaften*, May 7, 1926.)—Such divergent opinions are held upon the subject that it is a pleasure to learn the matured conclusions reached by this distinguished chemist. After the establishment of the views of atomic structure now prevalent, Ramsay was the first to attempt to transform one element into another. He let α-rays from radio-active substances act upon aqueous solutions and at first it seemed that small quantities of newly formed elements appeared, especially of neon and lithium. Subsequent experiments, however, negatived his results. In recent years Rutherford and his school have taken up the same problem and have had for the identification of new elements a method much more delicate than that of chemical analysis used by Ramsay. Elements were bombarded with alpha particles and the resulting fragments of atoms announced their existence by the flashes they caused on a zinc sulphide screen. By deflecting them in a magnetic field Rutherford showed them to be hydrogen nuclei. No less than twenty-seven elements have thus been made to produce hydrogen in the laboratories of England and Vienna, and the chase is still on. The important thing is that a sort of enforced radio-activity has been demonstrated to occur in the case of the light elements. Previously the heavy and still radio-active elements were regarded as remnants of a time when other elements were probably leading a wild radio-active youth from which they settled down to a staid and uneventful life.

The reason of Ramsay's failure lay in the crudity of his method of detection. To transmute an element the nuclei of its atoms must be struck and splintered, but these nuclei are so small that only one α-particle in a million hits a nucleus, although it may pass through 100,000 atoms in its career. Hence the quantity of disintegrated matter produced is below the limit of chemical analysis. To bring it within the possibility of detection by chemical means it might seem only necessary to increase the number of α-particles in the bombardment and this could actually be done by anode rays. Number, however, is not all that counts. To break up a nucleus a particle must have a speed of at least 15,000 km. per sec. This means that it must fall through a potential difference of 2,000,000 volts and technical resources cannot at present meet this demand.

There remains another method of transforming an atom of one element into the atom of a different element besides that of breaking it into pieces. An atom of mercury consists of 80 electrons revolving around a nucleus with a charge of 80 positive units. If an electron could be made to attach itself to the nucleus, the charge of the

latter would be reduced to 79 positive units with only 79 electrons in its planetary system. But such an atom is an atom of gold. Many had probably thought of this transmutation as possible before Miethe and Stammreich announced that they had got gold from mercury in a mercury lamp in such quantity that it had been detected by chemical means. At that time Professor Haber was on a tour around the world—he was present at the Centenary of The Franklin Institute in 1924—and in Japan he came upon Nagaoka, who believed that he too had accomplished the change of mercury into gold and that quite independent of the German investigators and by a different process. They used the considerable current and relatively small voltage of a lamp while he employed the discharge from an induction coil that gave a spark 125 cm. long. In the German experiment a host of electrons were sent against the mercury atoms, but with a small velocity. In Japan the speed of the assailing electrons was much greater. After his return to Berlin the author repeated the transmutation experiments with the help of Jaenicke and Matthias. Meanwhile other considerations were coming into the foreground. At Berlin, Riesenfeld and Haase had studied the distillation of mercury containing gold and called attention to the fact that Miethe's mercury had not been distilled in such a way as to assure its freedom from gold. In the same university Tiede, Schleede and Goldschmidt repeated Miethe's experiment with exceptionally pure mercury and failed to get any positive result. In the United States Sheldon, Estey and Maily repeated Miethe's work with mercury originally free from gold and they too found no gold at the end of the process. Miethe and Stammreich repeated the experiment by a modified method and again found traces of gold. Haber and Jaenicke devised an analytical method of detecting gold so sensitive that when .0001 mg. gold was added to 10 g. mercury; all but 10 per cent. of the added gold was recovered at the end of the analysis. They prepared mercury that showed no trace of gold when tested by this method. With this mercury they repeated Nagaoka's experiment and really found gold at the end to the extent of .0000001 g. They then performed experiments in a manner prescribed by Miethe and failed to find a trace of gold. They tried again with improved electrical equipment and got less than .000001 g. of gold, but the significant point was that there was no more gold after a run of fifty-six hours than after one of four hours. The work was repeated with additional modifications. Gold was obtained. Later the same apparatus was used again and only about 1/1000 as much gold was got as in the first trial. An examination of the metallic leads showed them to contain gold, though the leads after the apparatus had been used had lost all but 1/40 of their gold. Electrolytic copper wire, nickel wire, steel screws and Swedish iron of low carbon content all contained traces of gold and silver. Only tungsten wire showed itself free of gold. The possibility of accidental contamination with gold is great. A collaborator of Professor Haber suddenly discovered traces of gold where others

found none. It came to light that, when he made an observation, he took off his spectacles. Then with the fingers that had touched their gold frame he picked up a piece of pure lead and put it in the crucible. This sufficed to introduce a trace of gold where there had been none. The author concludes: "It is seen that no success has been achieved in changing mercury into gold in such quantity as to be detected by chemical means. The amounts of gold which we obtained and which at first appeared to us to confirm the results of Miethe and Nagaoka did not increase in the progress of lengthy investigations and are to be explained as impurities coming from the electrodes. No one will by reason of a failure abandon the hope of eventual success in solving the problem of the alchemists." G. F. S.

Rare Metals Mining in the United States for the Year 1924.—Bulletin 1–22 of the Department of Commerce, Bureau of Mines, summarizes the results of mining of the following metals in the United States: Cobalt, molybdenum, nickel, tantalum, titanium, tungsten, radium, uranium and vanadium. The application of the term "rare" is probably with reference to the occurrence of these metals in the United States, as some of them seem to be comparatively abundant elsewhere. Cobalt is now used largely in making a group of alloys known as stellite which are employed for cutlery on account of their resistance to corrosion. No cobalt minerals were mined in the United States in 1924. The world's needs have been largely supplied from Canada and Australia. In the year 1924 molybdenum ore was mined to an amount of nearly 300,000 lbs. of that metal. Nickel is usually produced as a by-product of the electrolytic refining of domestic and foreign blister copper. With this metal also the principal supply for use in this country is from Canada. Of tantalum the only known output in the United States is in South Dakota, the yield for the year of the report being about 1200 lbs. of ore. The principal supply of titanium is from ilmanite obtained from the beach sands in Florida. Titanium is now used in the production of a pigment. The production of tungsten was increased, but is still small compared with that of the ten years preceding the close of the war.

Mining of radium was done in the uranium-vanadium fields of the United States, but more work was done on vanadium itself. As the uranium ores are practically all used by the United States Radium Company and only two companies produce vanadium salts, no figures for domestic production may be given. The radium market was dominated by the output of the Belgian Congo. In 1923 nearly 4000 tons of uranium ore were mined there. The uranium or radium content has not been made known, but indirect information indicates that the ore carries from 40 to 70 per cent. U_3O_8, though likely much of the ore is leaner. As each per cent. means about 2.5 milligrams of radium per ton of ore, it is seen that the total yield is rather large. The total sales from these Congo mines to the end of 1924 are said to

have been 35 grams of radium. The costs are not given but are said to be only a few dollars per milligram. This competition, as is well known, caused the closing down of nearly all work on the radium deposits in the United States. As the difficulty was insuperable and could not be foreseen, a bill was introduced in Congress asking that owners of carnotite claims be freed from the assessment work on their claims for three years. After hearings before the Committees on Mines and Mining of the House of Representatives the bill was favorably reported but was not acted on. H. L.

The Wettest and Dryest Spots on Earth (note, H_2O, not C_2H_5OH).—Mention was made in a recent issue of the hottest place on the earth's surface. Mark Jefferson, in the *Geographical Review* (1926, **16**, 324), presents data as to the coldest place and also places of highest and lowest annual rainfall. The lowest temperature so far noted was –67.8° C. (–90° F.) at Verhoyansk in Siberia in January, 1885 and 1892. Long rainfall records at a point on the plateau northeast of Calcutta at an elevation of 1250 metres (about 4200 feet) show annual falls ranging from 427 to 449 inches, more than ten times that of the average of the eastern United States. Observations at a near-by point on the same plateau showed a fall of almost 500 inches, but such a record is not comparable with the long ones. At a point in the Hawaiian Islands a fall of 561.86 inches was noted in 1918. The least fall observed in long periods is in the Chilian (nitrate) desert, 5 millimetres (about one-fifth inch) having been recorded at Iquique. High annual rainfall is not necessarily coincident with very frequent rains, as the precipitation may often be small. At a point in the Marshall Islands, 336 rainy days have been noted in one year. A traveller in the Orinoco basin said that in the dry season it rained every day and in the wet season all the time.

H. L.

Illuminating Engineering Society, Twentieth Convention.—The Twentieth Anniversary Convention of the Illuminating Engineering Society is to be held at Spring Lake, N. J., from September 7th to 10th, inclusive. The Convention will commemorate the completion of twenty years of progress in furthering the objects of the society; and the great advances and developments which have been made during this period, in which the society has taken such a prominent part, will be fittingly observed.

A program of diversified and comprehensive papers has been arranged by the Committee on Papers, including subjects of great practical interest. A special feature of the program, particularly appropriate at this time, will be a session devoted to developments in the art of illumination which have taken place during the twenty years of existence of the society. Another session, which will be of interest to central-station lighting men, will be devoted to the presentation and discussion of the Lighting Sales Manual, prepared by a

joint committee of the Illuminating Engineering Society and the National Electric Light Association. The manual outlines methods found most efficient in promoting good lighting by central stations by some of the leading illuminating engineers of the country. Central-station lighting men from the leading public utilities are to be invited to discuss the manual and promote its adoption and use.

Under the auspices of the Committee on Natural Lighting, there will be presented a series of interesting and practical papers covering a variety of subjects such as the effect on illumination of dirt accumulation on glass, distribution characteristics of various types of glass, natural lighting in schools, and the relative effectiveness of various methods of light control through windows. Other papers depicting the great part that lighting can perform in the world's work and in its relation to human happiness will be discussed.

The convention will bring to a close the first twenty years of the society's existence, but it will likewise mark the beginning of a new era in which lighting is destined to become increasingly important in the world's activities. R.

The Mechanics of the Electric Field. SIR J. J. THOMSON. (*Electrician*, April 30, 1926.)—On a day in April, British electrical engineers heard three notable addresses. Mr. Samuel Insull spoke at a luncheon on the "principles that are actuating those who are responsible for electricity supply in the United States." In the evening Sir J. J. Thomson discussed the abstruse problems of the electric field. He laid aside his manuscript and notes and gave to his auditors the privilege of hearing a great leader in science think aloud. Then Sir Oliver Lodge followed in a brilliant speech of comment.

Sir J. J. Thomson's address was the seventeenth Kelvin Lecture. The speaker assumed the structure of the atom with its electrons and positively electrified particles. Not only is the number of electrons known for the atom of an element, but we have a specification of their arrangement about the nucleus. With so detailed a knowledge of structure it was hoped that from the application of the recognized laws of electricity and magnetism it would be possible to deduce the actual properties exhibited by atoms. This hope has not been realized in full. "It was a tremendous extrapolation to pass from the conditions under which these laws had been established by direct experiment to conditions like those in the atom where the times and the distances involved were of an entirely different order. The ordinary laws of electromagnetism and of the dynamics of the electric field merely represented the relations between averages taken over a time which, though small, was finite and comparable with the times that occurred in the atom. These relations were meaningless when times less than the times for which the averages had been taken were considered." Without definitely committing himself to the view he discussed the results that would follow were both the positive nucleus

and the electron surrounded by a swarm of smaller particles in rapid motion. He states that the principle of the conservation of energy when applied to electronic orbits does not hold except on the average. A consideration of the times involved seems to explain how an electron can go on circulating in its orbit without constantly radiating energy.

In relation to the vexed question of reconciling the quantum theory with the wave theory of light, he gave his opinion that the emitted bundles of energy "consisted of a series of electrical waves bounded by a region where the energy had fallen to a definite value, the centre of that region containing the quantum."

In the latter part of his lecture the Master of Trinity appears to have given his adhesion more completely to the existence of particles smaller than electrons. In this view lies the significance of the lecture. G. F. S.

Weather Bureau and Commercial Aviation. (U. S. Department of Agriculture, Press Service, July 9, 1926.) Included in the deficiency bill just passed by the Sixty-ninth Congress is an appropriation of $75,000 for the Weather Bureau of the United States Department of Agriculture for establishing and maintaining twenty-one additional pilot balloon stations at certain points along civil airways, including those operated by and for the Post Office Department. This bill supplements the Air Commerce Act approved May 20, 1926, which specifies that it "shall be the duty of the Secretary of Commerce to make recommendations to the Secretary of Agriculture as to the necessary meteorological service" along civil airways.

The deficiency bill also provides funds for the use of the Department of Commerce in connection with this work, and the two departments will coöperate closely in carrying on the service. The Weather Bureau is to "furnish such weather reports, forecasts, warnings and advices as may be needed to aid the safety and efficiency of air navigation in the United States and above the high seas, and particularly along the civil airways designated by the Secretary of Commerce." It will therefore "observe, measure and investigate atmospheric phenomena and establish meteorological offices and stations."

The service desired is, first, information as to current conditions, both surface and upper air, along the section of the airway over which flight is to be made; and second, a forecast as to conditions over that same route for the next four to six hours. In other words, a pilot wants to know what the weather and wind conditions are now at all points over which he is to fly, and, as nearly as meteorologists can tell him, what changes will occur during the time required for his flight. This time averages three or four hours, but is occasionally five or six, when there is a strong head wind. Forecasts for longer periods are not essential in aviation. If a pilot is to leave at two o'clock for a four-hour flight, a general forecast issued at 8 A.M. is of little use to him; what his experience has shown that he needs

is information at 1.45 o'clock P.M. as to conditions then prevailing, and a prediction, based upon these conditions, for the next five hours. This means of course that observations will not be taken simultaneously at all points along an airway, but at varying times depending upon the aviation schedules. Special observations will be required of surface and low-level conditions, such as visibility, fog, squalls, thunder storms, and other unfavorable phenomena. Wind direction and velocity and heights of clouds will be determined by pilot balloon observations.

A glance at the post-office air mail map shows the chief routes that will be helped by the new service. Commercial aviation in general is most active over these designated airways, because of the convenience of landing places, fuel supplies, available upper air information, and other considerations. The transcontinental route from San Francisco to New York is the only route now operated by the Post Office Department. Feeding into this are twelve contract routes which include all the points where stations will be opened by the Weather Bureau and special service maintained during this first year. Ten will probably be in operation within a month or two after the first of July and the others, depending on the success of the Weather Bureau in procuring suitable equipment, it is hoped will be in operation by November. Eight of these stations are located along the transcontinental line, the remainder on the contract lines.

Commercial aviation of many kinds in addition to mail carriers will be benefited by the safeguarding of the airways through the new service. Passenger traffic is relatively undeveloped in the United States in comparison with Europe, but is increasing as safety measures are added. The use of airplanes for express and special delivery of all kinds is tremendously varied. It may include almost any articles from truck garden products to jewelry. Three pianos recently received country-wide advertising from this method of quick delivery, but while such cases might be rare, the use of planes for sending films on motion picture circuits saves valuable hours and consequently greatly increases box office receipts. Other recognized uses for commercial airplanes are for forest fire patrol work and for distributing insecticides on a large scale in insect control work. This method of scattering poison dust has been used successfully over cottonfields, peach orchards, mosquito breeding places, and in numerous other ways. It has already passed the experimental stage and is rapidly becoming a factor of importance in the economic life of the nation. R.

Motive and Obligation. F. B. JEWETT. (No. 68, Reprint and Circular Ser., Nat. Research Council.)—The author, the president of the Bell Telephone Laboratories, directs attention to the growing recognition of the practical value of research. This comes from a wide range of industries that have not, like those industries founded on chemistry and electricity, taken their origin from the laboratory.

In his own field he selects the electronic telephone repeater and the loading coil as very valuable contributions made by research to technical practice. "Were the Bell System to attempt to render without repeaters the long-distance telephone service for which they are now utilized, the additional cost of the heavier copper wires, the heavier pole lines and additional cable and underground ducts would amount to more than $20,000,000 a year." The first cost saving of the repeater from its first use in 1915 to 1923 is more than $160,000,000. The loading coil, invented by Pupin in 1900, is credited with saving about as much money as has the repeater. A century or more ago La Grange in connection with sounding bodies discussed the vibrations of a string loaded at intervals with weights. Pupin remarked the mathematical similarity of the transmission of electric waves over a pair of long wires to the propagation of mechanical vibration along the loaded string and the loading coil came into telephony. "Had La Grange been interested primarily in practical values, even one of his farsightedness would probably have passed over the problem of the loaded string as not worth consideration. I am positive no touchstone has been vouchsafed us by which we can at once determine even the approximate usefulness of scientific discoveries made in the quest of a broader knowledge." G. F. S.

Measurements of the Amount of Ozone in the Earth's Atmosphere and Its Relation to Other Geophysical Conditions. G. M. B. DOBSON and D. N. HARRISON. (*Proc. Royal Soc.*, A756.)—Before 1920 none but chemical methods were used to determine the amount of ozone in the atmosphere. Then Fabry and Buisson measured spectroscopically the intensity of the ultra-violet absorption band in the solar spectrum caused by ozone and calculated that the quantity of this substance is equivalent to a layer of pure ozone about 3 mm. thick at normal pressure and temperature. The authors have applied a method like that of the French savants on every day of the year 1925 on which observations were possible. They give the values of the depth of the layer of ozone for days in every month except January and December. The greatest depth was 3.7 mm. on February 28th and the smallest 1.9 on October 17th.

There appears to be an annual period with its maximum in the spring and its minimum in the fall. No sure evidences of a twenty-seven-day period or of a diurnal period have been found. When the curves showing depth of ozone and those for atmospheric pressure are compared a surprising parallelism is noted. It is supposed that the ozone in the atmosphere is situated not in the troposphere but above it. Hence one would expect the quantity of ozone to be connected with conditions in the upper atmosphere rather than with such a feature of the lower air as its pressure. Furthermore, Dines has shown a correlation coefficient of only .68 between the pressure at the earth's surface and that existing at the same time at an altitude of 9 km. above it. In spite of these facts there does exist a definite

relation between the pressure at the surface of the earth and the quantity of ozone in the higher ranges of the atmosphere. "There appears to be a tendency in the amount of ozone to reach a maximum a day or two after the extremes of pressure, and this is quite as marked with anti-cyclones as with cyclones."

No matter whether the ozone in the high atmosphere is due to the action of ultra-violet light from the sun or to electrical discharges of the aurora, there may well be some connection between solar activity and the amount of this substance present. An examination of the sun-spot numbers shows that its quantity increases when the number of sun-spots grows less. G. F. S.

Oil Must be Made to Disappear from Sea. (*Science News-Letter*, 9, No. 273, July 3, 1926.)—Representatives from twelve nations attended the recent International Conference on Oil Pollution in Washington to see what can be done to make the oil discharged from vessels vanish from the high seas.

The rapid increase in the number of oil-burning ships has rendered the matter of water pollution from the waste oil a matter of world importance, for the discharge, being insoluble in water, is driven ashore by the wind with serious detrimental effects on bathers and fish alike.

All attempts to pass regulations effecting total prohibition of discharge of oil at sea have been abandoned in favor of a system of permanent zoning. Vessels will only be allowed to make such a discharge not less than fifty miles off shore and not farther than 150. Zones can be established by a nation only with the consent of its neighbor nations, which in actual practice means that each country will have to work out its own particular zoning problem.

There was considerable discussion during some of the sessions of the installation of separating machinery that would reclaim fully 40 per cent. of the waste oil, it was said, which could be used over again. Since apparatus of this sort would pay for itself in a few years several delegates strongly advocated this solution of the difficulty. The high initial cost as well as increased tonnage, however, were felt by the majority to be arguments against oil separators.

The rest of the time allotted to the conference was taken up with the problem of enforcement of the regulations just passed, a question of major importance since legal jurisdiction over a vessel out at sea beyond the reach of observation is difficult to maintain. R.

Alleged Radio-active Waters and Drugs.—The alleged medicinal efficacy of slightly radio-active waters and other slightly radio-active preparations has been found to be much misrepresented, say officials of the Bureau of Chemistry of the United States Department of Agriculture, who, in the enforcement of the Federal Food and Drugs Act, have made a nation-wide survey of waters and drugs alleged to be radio-active.

The products analyzed for content of radium include hair tonics, bath compounds, suppositories, tissue creams, tonic tablets, face powders, ointments, mouth washes, demulcents, opiates, ophthalmic solutions, healing pads and other preparations in solid, semi-solid and liquid form for which therapeutic value, because of alleged radio-activity, was claimed. Only 5 per cent. of the products analyzed and claimed to be radio-active contained radium in sufficient quantities to render them entitled to consideration as therapeutic agents and then only in certain very limited conditions. Highly exaggerated therapeutic claims obviously designed to mislead the purchaser are being made for many of the products which contain little or no radium. One of the samples examined consisted of a short glass rod coated on one end with a yellow substance and enclosed in a glass bulb. The bulb is designed to be hung over the bed, and according to the claims of the inventor causes dispersion of "all thoughts and worry about work and troubles and brings contentment, satisfaction and body comfort that soon results in peaceful, restful sleep."

Action will be taken under the Federal Food and Drugs Act against shipments of the alleged radio-active products which are falsely or fraudently misbranded under the terms of the Federal Food and Drugs Act. A warning regarding the indiscriminate use of those few products which are highly radio-active is also sounded by the officials.

"The distribution to the general public without discrimination or adequate supervision of highly radio-active products or the devices for rendering water or other substances highly radio-active," says the department, "is of very questionable propriety since radium in active dosage is potent for harm as well as for good and should be administered with great caution." H. L.

Greenland Weather Stations. (U. S. Department of Agriculture, Clip Sheet No. 419, July 12, 1926.)—"Greenland's icy mountains," famed in the century-old hymn, are in reality one immense flat ice-cap extending two miles above sea-level and spread over a base of rock surface for hundreds of miles. Except for the margin along the coast, which is rough and broken like other arctic-ice formations, this ice is, so far as known, so smooth an airplane could land on it almost anywhere without difficulty. It has been represented by some that the special contour of this ice-cap causes the cold winds that form above it to develop hurricane velocities, and that they are influential in causing many of the severe North Atlantic storms that take heavy toll of life and shipping.

Scientists feel that meteorological observations should be taken at points where these winds originate, and such may ultimately be of great value to vessels at sea. To establish stations for making observations and for investigating other weather phenomena characteristic of Greenland, the University of Michigan has sent an expedition, which left Sydney, N. S., the last week in June, and will set up a

base at Holstensborg, Greenland. S. P. Ferguson has been loaned by the Weather Bureau of the United States Department of Agriculture to supervise the installation of the meteorological stations proposed by the expedition. He will direct the selection of sites for stations, serve as meteorologist in charge of all instruments and methods during three months this summer, conduct aerological work with balloons, and make observations of temperature, barometric pressure, clouds, wind-velocity, and directions and other conditions.

Another problem to be studied by the expedition is that of dealing with icebergs near their birthplace on the borders of Greenland's ice-cap. It is thought that it may be possible to break them up with explosives much as ice dams are broken, before they drift down to endanger shipping in trans-atlantic steamship lanes. This summer's expedition is chiefly for reconnaissance in preparation for the major explorations and studies to be made in 1927. R.

Dilatometric Investigation of the A_3 and A_4 Transformations in Pure Iron. SEIKICHI SATO. (*Phil. Mag.*, May, 1926.)—Pierre Curie, Weiss and Foex and others have investigated the magnetic changes accompanying these transformations. From his study of the concomitant physical changes Honda was led to conclude that the γ-iron existing before the A_4 transformation became thereby converted into α-iron. Since to the kind of iron resulting from this transformation the designation δ had been applied this conclusion meant that α-iron and δ-iron should be the same. A year later this was confirmed by X-ray analysis.

The aim of the present paper is to find whether the A_4 transformation is accompanied by an increase or a decrease of volume. At first a Honda dilatometer was tried, which functioned well for the A_3 transformation at 900° C., but which was useless for the A_4 transformation on account of the yielding of the silica tubes. A differential arrangement was substituted in which the change of length of a bar of cobalt was pitted against that of a bar, part of whose length was made up of cobalt and whose remaining length was iron. Cobalt was used because it has no transformation point in the temperature interval investigated and because, further, its coefficient of expansion, specific heat and melting-point are nearly the same as those of iron. The heat was applied by a carbon ring electric furnace, the temperature was measured by a Le Chatelier thermocouple. These with the differential bar with its indicating mirror were put in a water-cooled vessel from which the air could be removed.

When α-iron was raised in temperature from 610° C. onwards its length slowly grew less until about 875°, at which point a rapid contraction showed itself. This amounted to .00282 of the length of the iron rod. From 925° upward the γ-iron resulting from the transformation increased in length up to 1400°, where a very definite and rapid increase took place equalling .00085 of the length, or about one-third of the decrease at the A_3 point. The δ-iron resulting

from the transformation expands very little with rising temperature, if indeed it does not contract. Its course seems to be a prolongation of α-iron below the A_3 point. When iron is cooled down it goes through the changes of length in the reverse order. G. F. S.

Discussion on the Electrical State of the Upper Atmosphere. (*Proc. Royal Soc.*, A757.)—The importance of this subject in present scientific thought is attested by the discussion held by the Royal Society on March 4th and by the lecture delivered at The Franklin Institute five days later by Dr. E. O. Hulburt on "The Kennelly-Heaviside Layer and Radio-wave Propagation."

In opening the discussion Sir Ernest Rutherford pointed out that the existence of a conducting layer in the atmosphere is required to explain the daily variation of the earth's magnetism according to the views of Schuster and Chapman and also to account for the passing of electric waves around the earth. Eccles and others have shown that a region of ionized gases can both absorb and refract electrical waves passing through it. In this connection Sir Joseph Larmor has demonstrated by theory that the considerable length of the free path of the electrons in the higher atmosphere is of palmary importance in causing reflection and scattering of the waves. Rutherford himself feels that it is not yet known whether the electric waves that come down from the Heaviside layer are there reflected as from a mirror or are refracted so as to return to the earth.

S. Chapman states that through simultaneous readings of temperature and pressure made on sounding balloons we know the value of these two quantities in the air to a height of 25 km. From the average temperature at the surface of the earth of 285° abs. the temperature falls to 220° at the height of 10 km. Thence it remains constant up 25 or 30 km. From their observations on meteors Lindemann and Dobson inferred that the temperature of 220° persists to an elevation of 50 or 60 km. and that above this height there is a rather rapid rise of temperature to about 300° abs. at 140 km., where the air is warmer than at the ground. He finds it difficult to account for the presence of nitrogen and oxygen at the height of 500 km. By McLennan and Shrum's identification of auroral lines with lines of these gases they should exist wherever the aurora appears.

C. T. R. Wilson emphasized the importance of thunder storms upon the electrical state of the upper air. Statistical studies show that 1800 storms are going on all the time and that 100 flashes of lightning occur in a second. "Thus the power expended in producing lightning by all the thunder clouds in action at a given time is of the order of 10^{12} watts or 10^{19} ergs per sec., *i.e.*, about 1/10,000 of the energy received by the earth from the sun per sec." It may be that the thunder clouds maintain the potential difference of 1,000,000 volts that exists between the upper atmosphere and the earth and in some manner balance the downward current of 1000 amperes that flows

to the earth where good weather prevails. The high voltage of thunder clouds seem competent to render them sources of X-rays, of β-rays and of γ-radiation.

E. V. Appleton gave an account of the experiments made at Cambridge to get information concerning the upper atmosphere by short-distance transmission. Wireless phenomena require for explanation the existence of an ionized layer where the maximum number of ions per c.c. is from 10^5 to 10^6. Such a layer deviates long waves by reflection and short ones by magneto-ionic refraction. "Diurnal variations of wireless phenomena all seem to be explicable by assuming that the under boundary of the effective stratum is higher at night than during the day, and higher in winter than in summer. The evidence so far obtained indicates a day-time under-boundary at 50 to 70 km., which rises to 80 to 120 km. at night."

G. M. B. Dobson gave 110 km. as the most common height for the appearance of meteors and 80 km. and 45 km. as the two heights at which maximum numbers of meteors disappear. There is a region between 50 and 60 km. where few disappear. This suggests a difference between the atmosphere above this level and that below it. Other considerations likewise based on meteors show that the temperature of the atmosphere above 60 km. is much warmer than below it. This is accounted for by the formation of ozone in the upper air by the action of ultra-violet sunlight on oxygen. Ozone has absorption bands both in the visible and in the ultra-violet part of the spectrum and hence, since it is less transparent than other constituents of air to solar radiation, that region of the atmosphere where it exists should be warmer. Chree has shown that those days on which much ozone is present in the air are in addition marked by high magnetic character. This may be because the sunlight that produces the ozone at the same time develops ionization in the higher air.

F. A. Lindemann also spoke concerning the origin of the ionization of the air. He fails to find in the frequent thunder storms mentioned by C. T. R. Wilson an adequate explanation of the production of the ionization entirely above a certain height, which is required in order to account for phenomena noticed in wireless telegraphy. In day-time the action of sunlight provides a simpler cause, but this fails at night. "Ions caused by sunlight could scarcely persist in sufficient numbers at heights so low as are demanded." The aurora is too high and too fitful. If it can be established by experiment that ozone breaks up into ions, he holds that not only will the persistence of ionization at night be accounted for, but also the ascent of the ionized layer.

From this discussion emerges, on the one hand, the great advance made during the present century in acquaintance with the higher regions of the atmosphere and, on the other, the vast amount of our ignorance of conditions that seem to be weighty in determining important terrestrial phenomena. G. F. S.

Paris, Third Radio Show.—The third annual radio exhibition under the auspices of the Syndicat Professionnel des Industries Radio-électriques will be held in Paris at the Grand Palais des Champs-Elysées beginning October 23rd next. This exhibition will have the coöperation of nearly all of the industrial and commercial organizations engaged in the wireless field. The newest apparatus and the most recent devices will be shown and the display will be of especial interest to the amateurs who are interested in the progress in the field of wireless telegraphy and telephony. R.

The Frequency Distribution of Scientific Productivity. A. J. LOTKA. (*Jour. Wash. Acad. Sciences*, June 19, 1926.)—An endeavor is made "to determine, if possible, the part which men of different calibre contribute to the progress of science." A count was made of the number of names beginning with A and B in the decennial index of *Chemical Abstracts*, 1907 to 1916, to which 1, 2, 3, 4, etc., articles are credited. A similar count was made for Auerbach's *Geschichtstafeln der Physik*, the entire alphabet being examined. "In the cases examined it is found that the number of persons making two contributions is about one-fourth of those making one; the number making three contributions is about one-ninth, etc.; the number making n contributions is about $1/n^2$ of those making one." Assuming this relation, it can be shown that about 60.8 per cent. of all contributors should make a single contribution. In the *Chemical Abstracts* the actual proportion was 57.9 per cent. and in the Auerbach data 59.2 per cent. In the latter two people made no less than forty-eight contributions, while in the Abstracts Abderhalden is credited with 346 in a decade, though of these in some cases he was mentioned first of two or more joint authors. One may well ask whether this is a good way of comparing scientific ability. The number of papers might seem an index of persistence and industry rather than of ability. G. F. S.

On the Electrostatic Potential Energy, and the Rhombohedral Angle, of Carbonate and Nitrate Crystals of the Calcite Type. S. CHAPMAN, J. TOPPING and J. MORRALL. (*Proc. Roy. Soc.*, A757.)—At the Toronto meeting of the British Association in 1924 W. L. Bragg described how he had succeeded upon the basis of natural assumptions in calculating what the angle of a certain crystal should be. This paper is an extension of his method to a whole series of crystals of the calcite type, including six carbonates and the one nitrate, $NaNO_3$ crystallizing in the same type.

The crystals are regarded as composed of positive and negative ions, the metallic ions having positive charges and the CO_3 or NO_3 groups negative charges. The components of the crystal assume positions of equilibrium under the action of two sets of forces: (1) Electrostatic attractions and repulsions between the positive and negative ions, and (2) the repulsive forces that come into play in the